University of Bologna
Dipartimento di Informatica – Scienza e Ingegneria (DISI)
Engineering Bologna Campus

Class of **Computer Networks M** or
Infrastructures for Cloud Computing and Big Data

Global Stream Processing

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Stream Processing

There is more and more interest on **stream processing** … so

More and more set of tools are available to express and design a **complex streaming architecture** to be immediately deployed

- Apache **Storm**
- Yahoo **S4**

…

Stream Processing Challenge

- **Large amounts of data →**
  Need for **real-time views of data**
  - Social network trends, e.g., Twitter real-time search
  - Website statistics, e.g., Google Analytics
  - Intrusion detection systems, e.g., in most datacenters

- **Process large amounts of data**
  with latencies of few seconds
  with high throughput

Not MapReduce

The out-of-line workflow is not suitable at all

The typical **Batch Processing** → Need to wait for entire computation on large dataset before completing

In general those approaches are not intended for long-running stream-processing

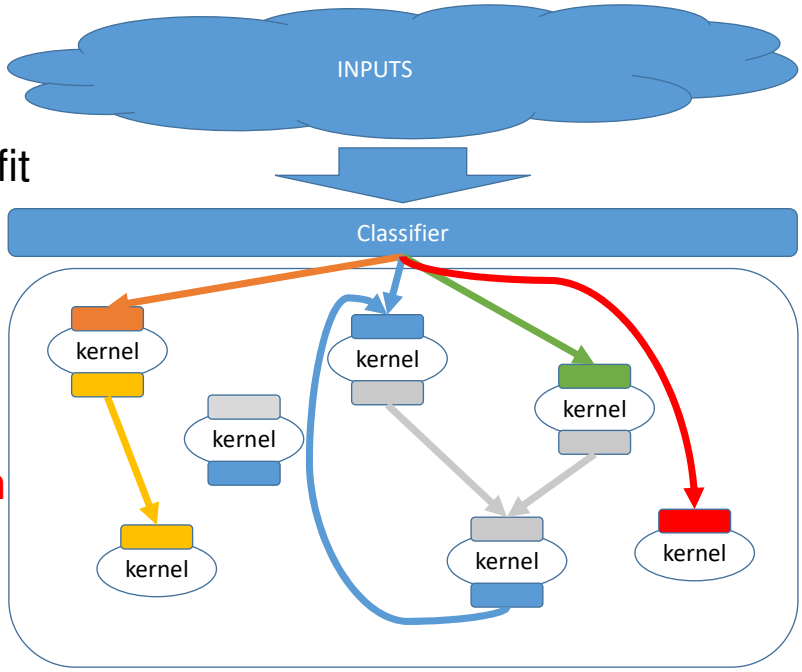
Stream processing model

Stream processing manages:

- **Allocation**
- **Synchronization**
- **Communication**

Applications that benefit most of the streaming model with requirements:

- **High computation resource intensive**
- **Data parallelization**
- **Data time locality**



Stream processing support functions

We need **available some basic functions** that can help in **mapping the concepts** we need to express

Storm is fast in **processing over a million tuples per second per node**: it is **scalable, fault-tolerant, respecting SLA** over data to be processed

Main functions must support the **stream processing** model:

- **Resource allocation**
- **Data classification**
- **Information routing in flows**
- **Management of execution/processing status**

Storm

- **Apache** Project **http://storm.apache.org**/
- Highly active **Java based** JVM project
- **Multiple languages** supported via user API
  - Python, Ruby, etc.

- Over 50 companies use it, including
  - **Twitter**: for personalization, search
  - **Flipboard**: for generating custom feeds
  - Spotify, Groupon, Weather Channel, WebMD, etc.

Storm Core Components

The Storm architecture is based on

- **Tuples**
- **Streams**
- Spouts
- Bolts
- Topologies
- …

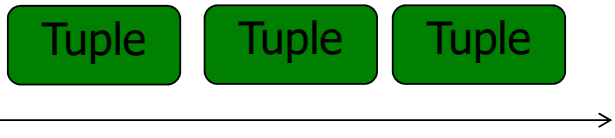
Tuple

The tuple is an ordered list of elements

- E.g., <tweeter, tweet>
  - E.g., <“Miley Cyrus”, “Hey! Here’s my new song!”>
  - E.g., <“Justin Bieber”, “Hey! Here’s MY new song!”>

- E.g., <URL, clicker-IP, date, time>
  - E.g., <coursera.org, 101.102.103.104, 4/4/2014, 10:35:40>
  - E.g., <coursera.org, 101.102.103.105, 4/4/2014, 10:35:42>

Stream



Sequence of tuples

Tuples potentially **unbounded in number**

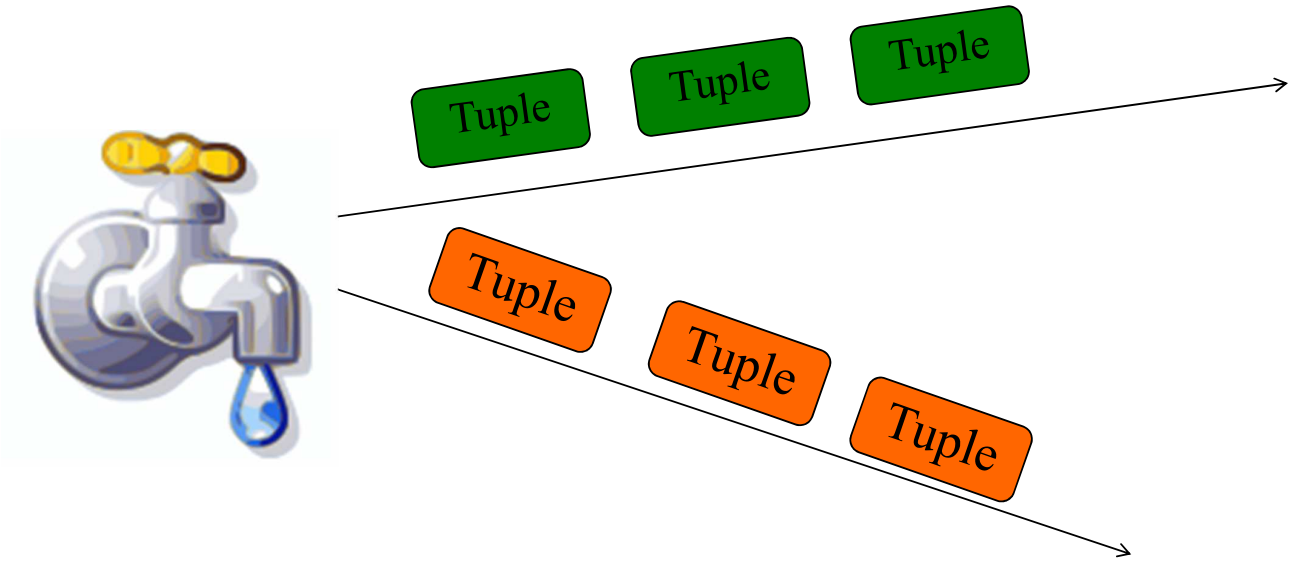
- Social network example:
  - <“Miley Cyrus”, “Hey! Here’s my new song!”>,
    <“Justin Bieber”, “Hey! Here’s MY new song!”>,
    <“Rolling Stones”, “Hey! Here’s my old song that’s still a super-hit!”>,
    …

- Website example:
  - <coursera.org, 101.102.103.104, 4/4/2014, 10:35:40>,
    <coursera.org, 101.102.103.105, 4/4/2014, 10:35:42>, …

Spout

One **spout is a Storm entity** (process) that is a source of streams

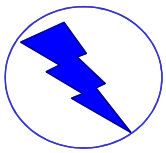
- Often reads from a crawler or DB

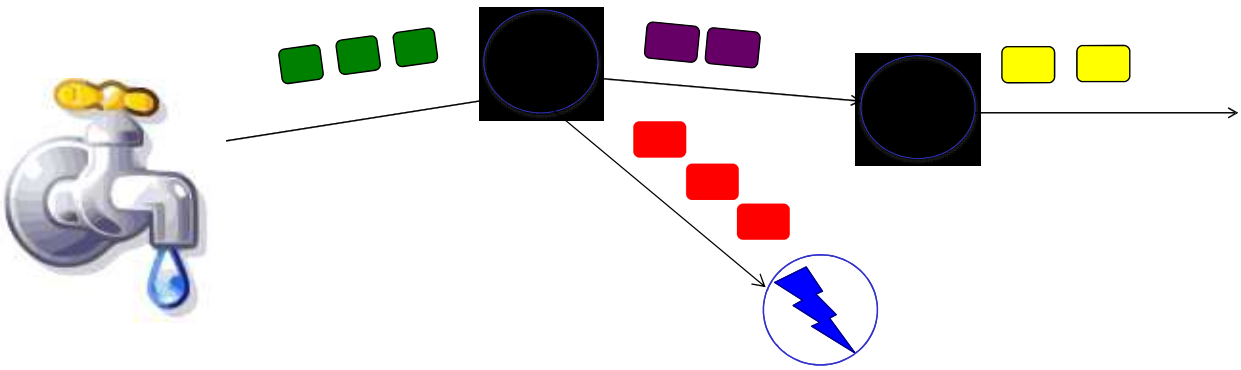


Bolt

A **bolt is a Storm entity** (process) that

- Processes input streams
- Outputs more streams for other bolts

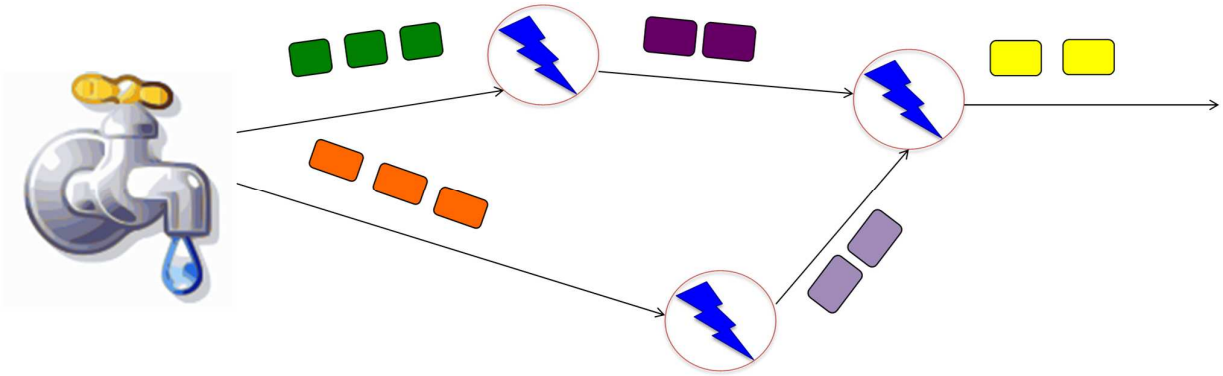




Topology

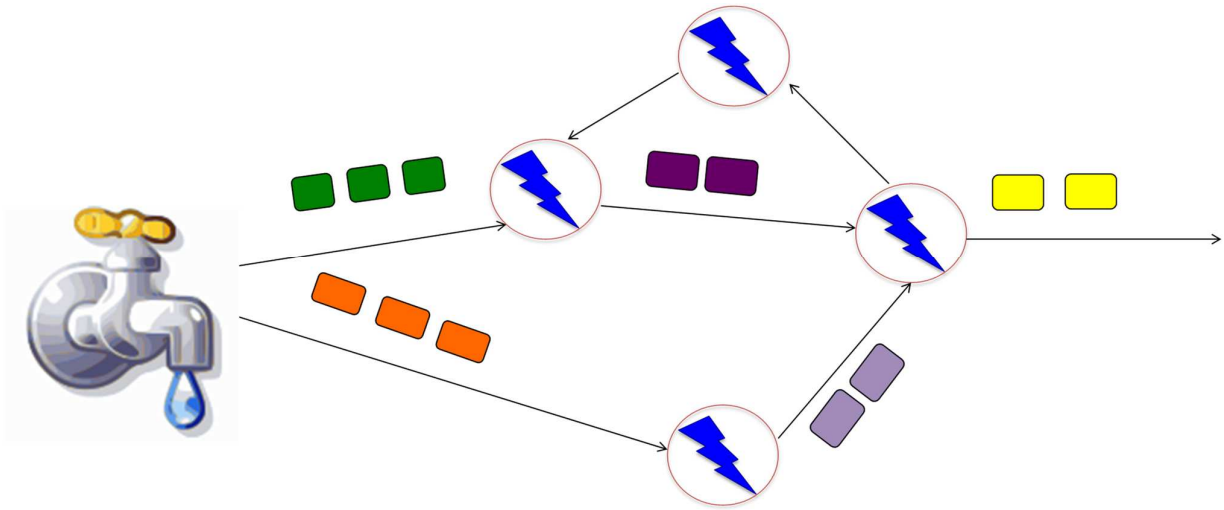
A **directed graph** of **spouts** and **bolts** (and output bolts)

- Corresponds to a Storm “application”



Topology

A **Storm topology** may define an architecture that can also have **cycles** if the application needs them



Bolts come in many Flavors

Operations that can be performed

- **Filter**: forward only tuples which satisfy a condition
- **Joins**: When receiving two streams A and B, output all pairs (A,B) which satisfy a condition
- **Apply/transform**: Modify each tuple according to a function
- …And many others

But bolts need to process a lot of data

- Need to make them fast

Parallelizing Bolts

- **Storm** provides also **multiple processes ("tasks") that can constitute a bolt**
- **Incoming streams** split among the tasks
- Typically each **incoming tuple goes to one task** in the bolt
  - Decided by "Grouping strategy"
- Three **types of grouping** are popular

Grouping

- **Shuffle Grouping**
  - Streams are distributed evenly among the bolt's tasks
  - Round-robin fashion
- **Fields Grouping**
  - Group a stream by a subset of its fields
  - E.g., All tweets where twitter username starts with [A-M,a-m,0-4] goes to task 1, and all tweets starting with [N-Z,n-z,5-9] go to task 2
- **All Grouping**
  - All tasks of bolt receive all input tuples
  - Useful for joins

Failure behavior

Also **failures can be mapped**

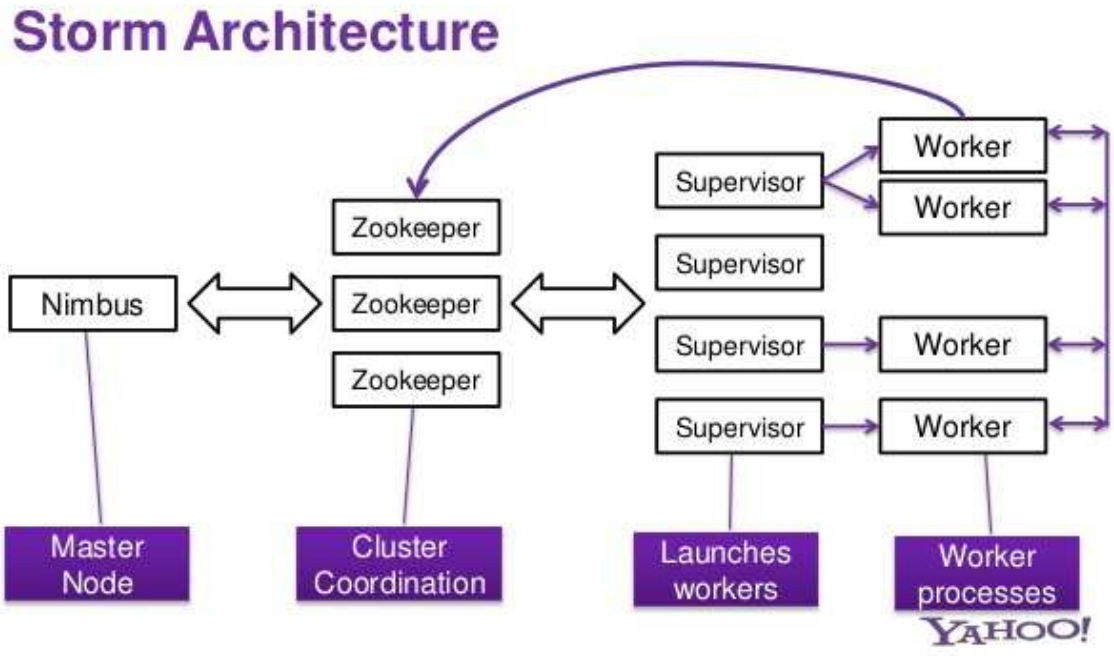
- A tuple is considered failed when its topology (graph) of **resulting tuples fails to be fully processed within a specified timeout (time dimension)**
- **Anchoring**: Anchor an output to one or more input tuples
  - Failure of one tuple causes one or more tuples to be replayed

API For Fault-Tolerance (OutputCollector)

- **Emit** (tuple, output)
  - **Emits an output tuple**, perhaps anchored on an input tuple (first argument)
- **Ack** (tuple)
  - Acknowledge that a bolt **finished** processing a tuple
- **Fail** (tuple)
  - Immediately fail the spout tuple at the root of tuple topology if there is an exception from the database, etc.
- Must Record the **ack/fail of** each tuple
  - Each tuple consumes memory. Failure to do so results in memory leaks.

Storm Cluster

Several components in a Cluster



Zookeeper

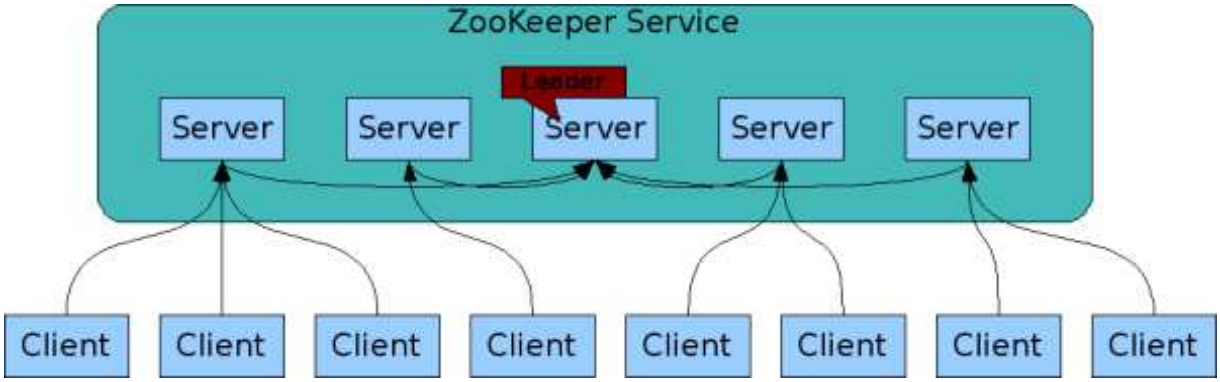
ZooKeeper is an open-source Distributed Coordination Service for Distributed Applications

- ZooKeeper can propose a unique **memory space with very fast access in reading and writing with some quality** (QoS: replication is paramount and dynamicity too)
- ZooKeeper relieves distributed applications from **implementing coordination services** from scratch
- Zookeeper exposes a simple set of primitives to implement **higher level services for synchronization, configuration maintenance, and groups and naming**
- The data model is shaped after the familiar **directory tree structure of file systems** and it runs in Java with bindings for both Java and C

Zookeeper

ZooKeeper is seen as **a unique access space with very fast operations to read and write data with different semantics (FIFO, Atomic, Causal, …)**

Data are dynamically mapped over several nodes and **their location can be dynamically changed and adjusted without any actions of clients**



Storm Architecture

Storm allows to:

1. First express your need **in streaming via its components** you can easily define and design
2. Secondly, configure your **capacity needs over a real architecture** so to produce a controlled execution
3. Then **operate it over different architectures**

Storm Cluster

- **Master node**
  - Runs a daemon called *Nimbus*
  - Responsible for
    - ✓ Distributing code around cluster
    - ✓ Assigning tasks to machines
    - ✓ Monitoring for failures of machines
- **Worker node**
  - Runs on a machine (server)
  - Runs a daemon called *Supervisor*
  - Listens for work assigned to its machines
  - Runs “Executors”(which contain groups of tasks)
- **Zookeeper**
  - Coordinates Nimbus and Supervisors communication
  - All state of Supervisor and Nimbus is kept here

Twitter Heron System

Fixes the inefficiencies of Storm acknowledgement mechanism (among other things)

By using **backpressure**: a **congested downstream tuple** will ask upstream tuples to slow or stop sending tuples

1. **TCP Backpressure**: uses TCP windowing mechanism to propagate backpressure
2. **Spout Backpressure**: node stops reading from its upstream spouts
3. **Stage by Stage Backpressure**: think of the topology as stage-based, and propagate back via stages

- By using:
  - Spout+TCP, or
  - Stage by Stage + TCP
- Heron beats Storm throughput

S4 Platform

Simple Scalable Streaming System (S4)

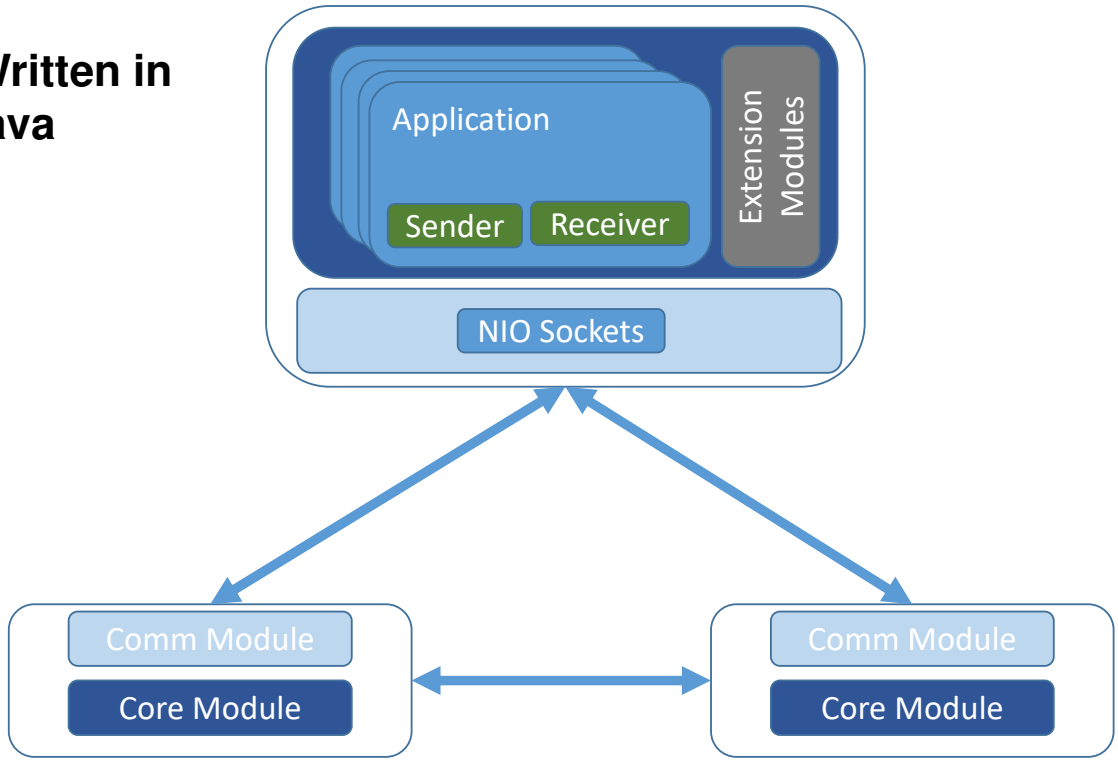
S4 is a **general-purpose, near real-time, distributed, decentralized, scalable, event-driven, modular platform** that allows to implement applications for processing **continuous unbounded streams of data**

Design goals:

- **Scalability**
- **Decentralization**
- **Fault-tolerance (partially supported)**
- **Elasticity**
- **Extensibility**
- **Object oriented**

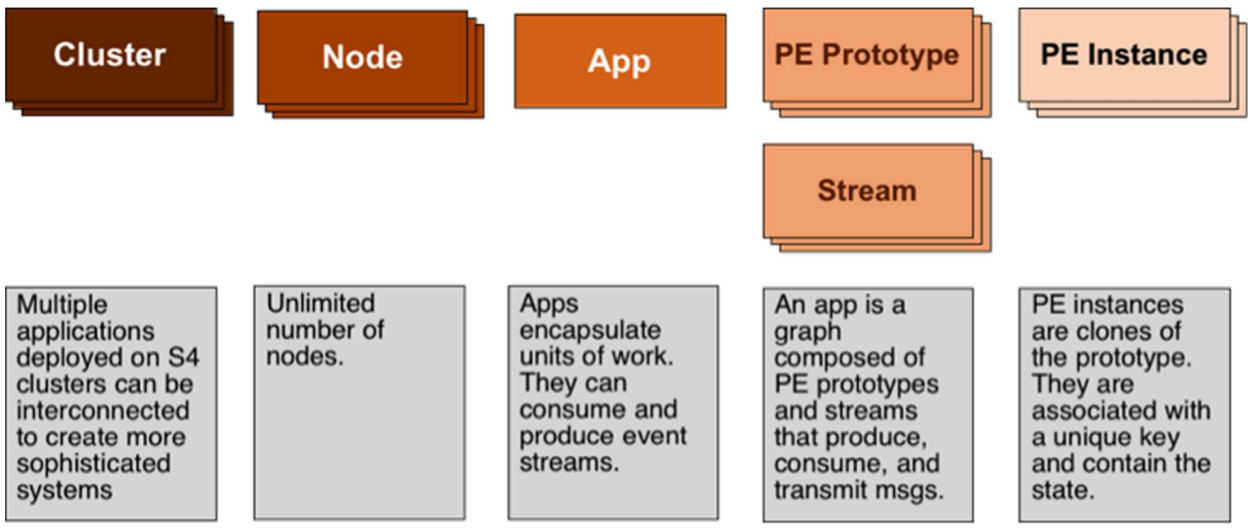
S4 Platform - architecture

Written in java

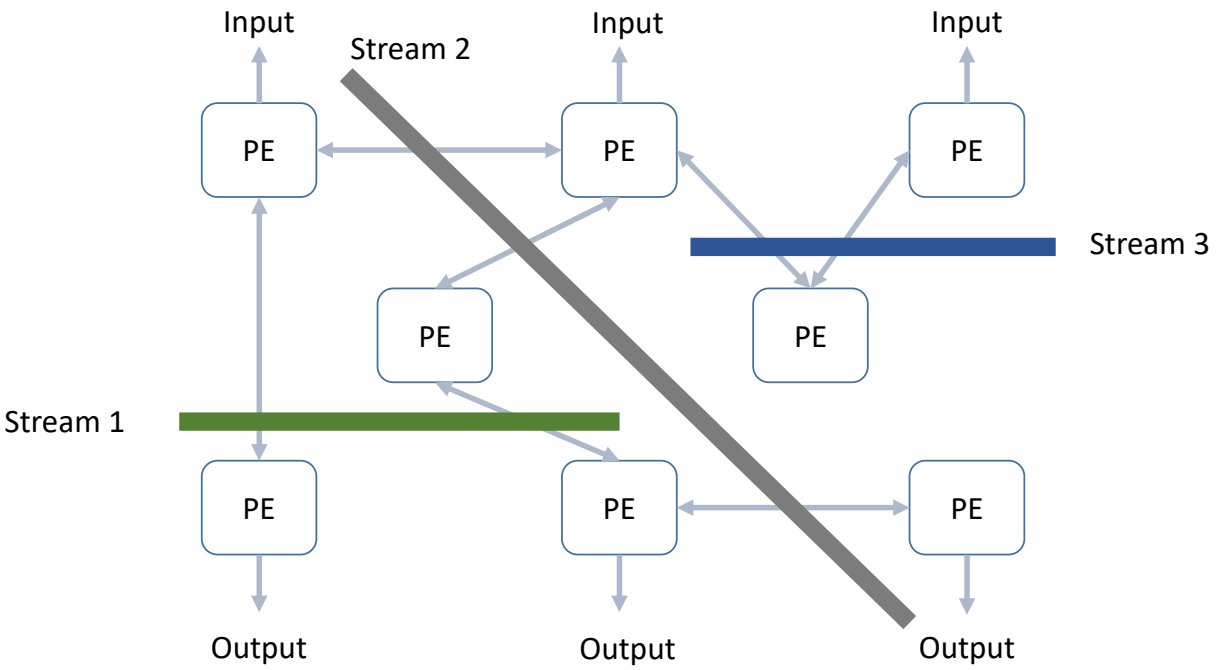


S4 Platform - components

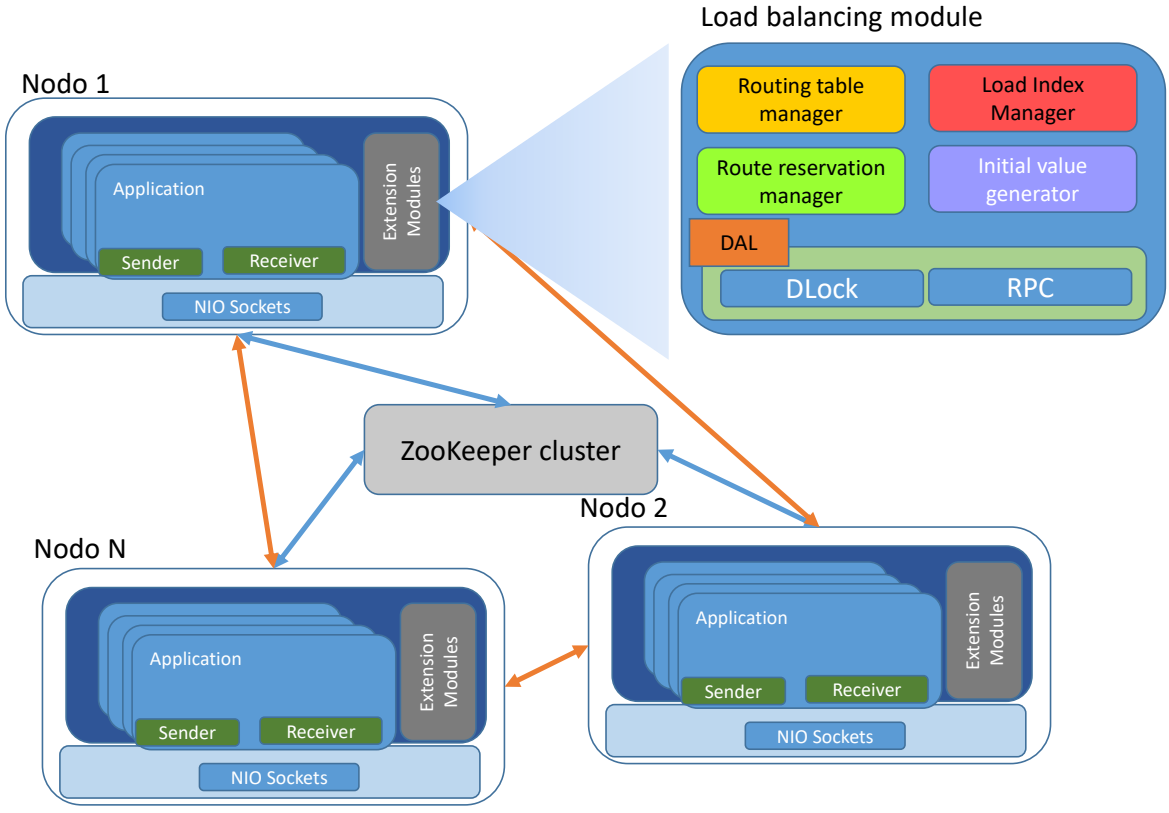
S4 based on several simple components that can be put together



S4 Platform - application



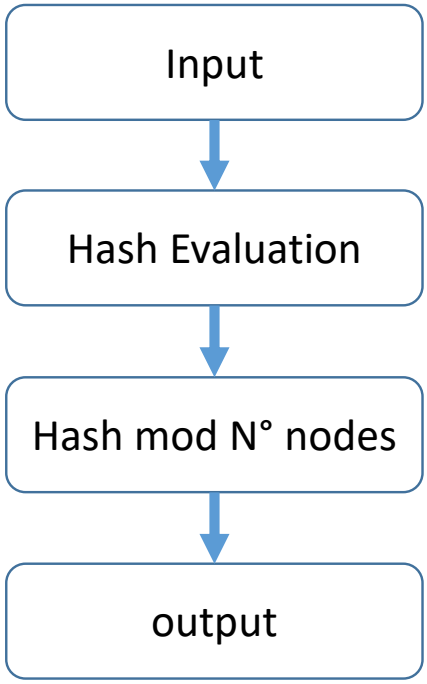
S4 Platform – overall view



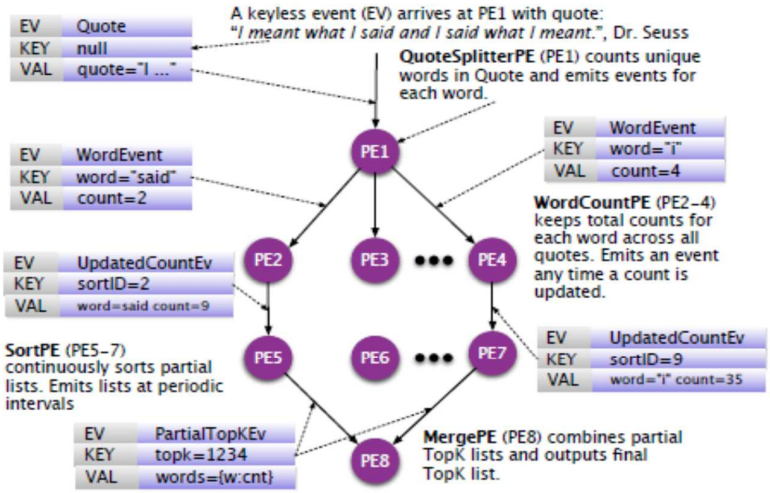
Load balancing support & open issues

Not really supported…

- **Load sharing on cluster nodes based on very simple hash functions**
- **There is no real load balancing support**
- **No guarantees of effectively balanced load sharding**



An example: Word Count (sounds familiar?)



PE ID	PE Name	Key Tuple
PE1	QuoteSplitterPE	null
PE2	WordCountPE	word="said"
PE4	WordCountPE	word="i"
PE5	SortPE	sortID=2
PE7	SortPE	sortID=9
PE8	MergePE	topK=1234

Figure 1. Word Count Example

For details, refer to the S4 presentation paper: L. Neumeyer *et al.*, *"S4: Distributed Stream Computing Platform"*, KDCloud 2010