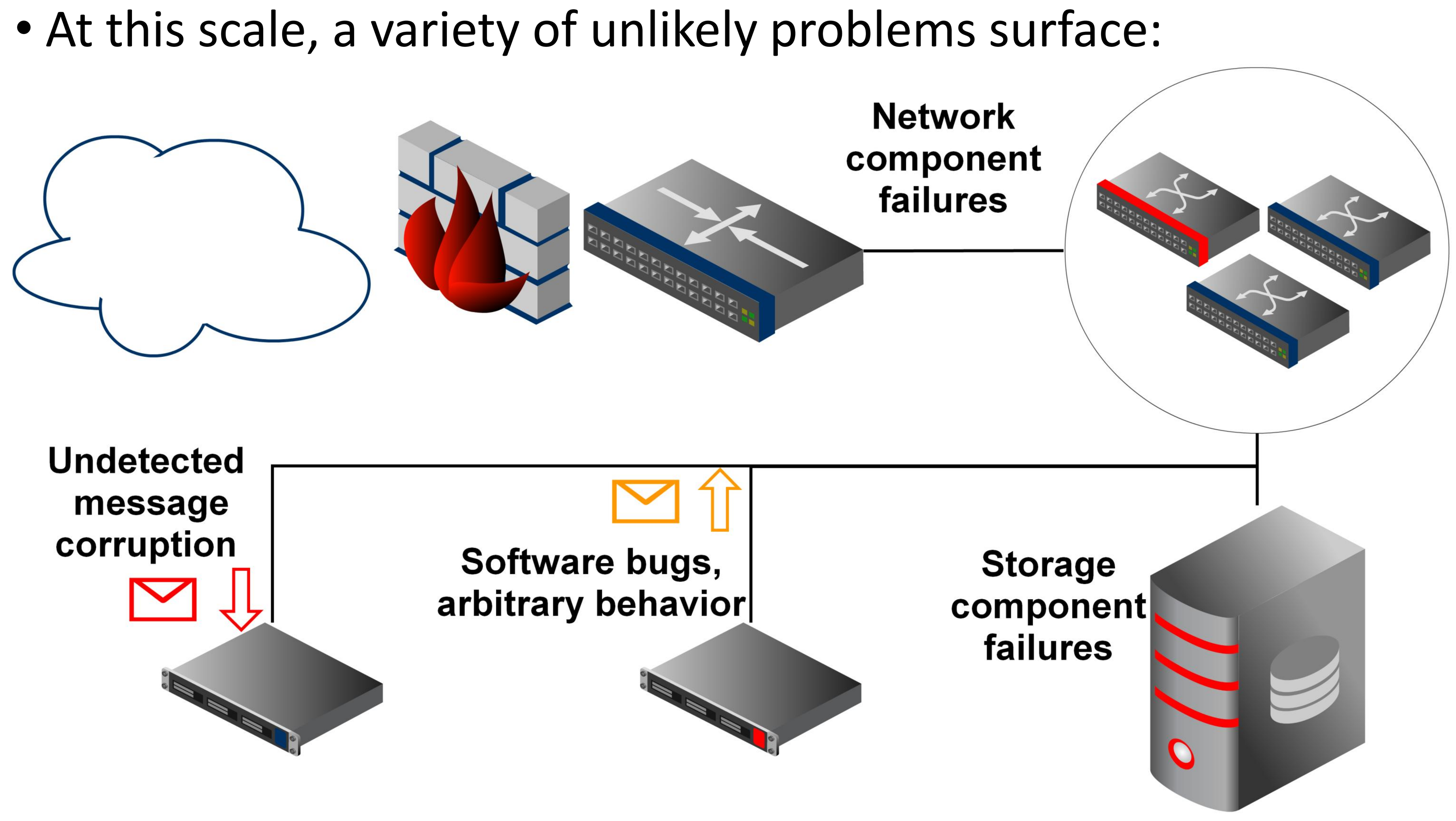
Improving the Dependability of Data Center-Scale Computations

Daniel Porto[*], Aniket Kate[*], Rodrigo Rodrigues[*], Pramod Bhatotia[*], Alexander Wieder[*]
Flavio Junqueira[†], Benjamin Reed[†]
Max Planck Institute for Software Systems (MPI-SWS)[*], Yahoo! Research[†]

1. Context

- Increasing amount of data being processed in large data-centers
- At this scale, a variety of unlikely problems surface:



The two broad classes of fault models are not well suited

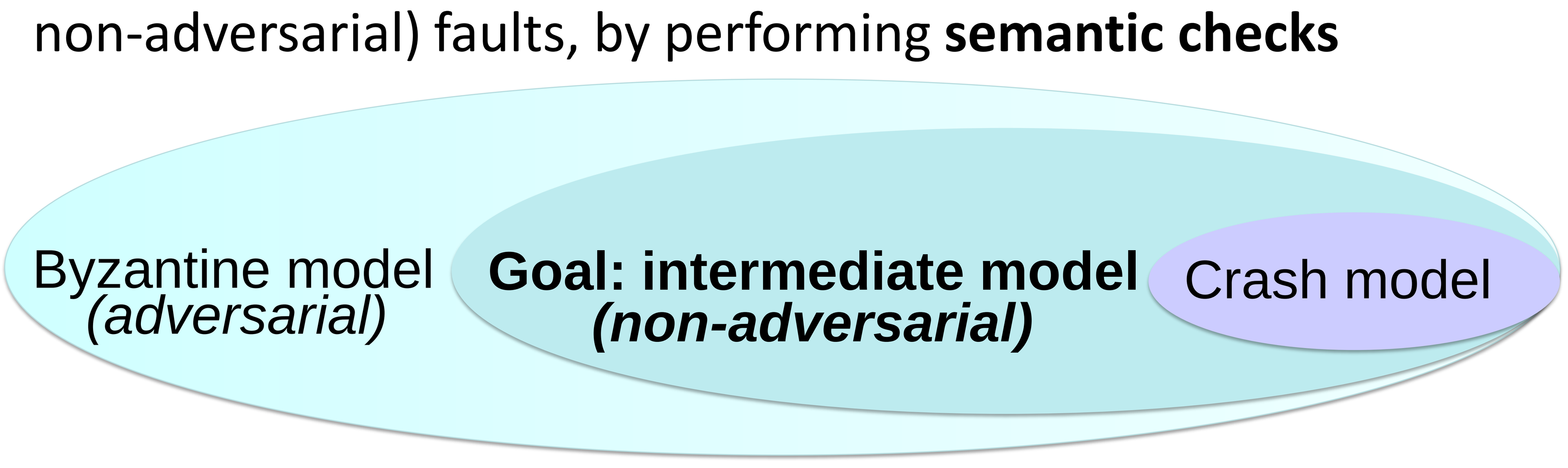
Crash model: insufficient; does not cover arbitrary behavior

Byzantine model: considered overkill; internal data-center infrastructure is well protected against malicious adversaries

- *Ad hoc* solutions have been applied (e.g., CRCs to protect state) – difficult to guarantee full coverage

2. Basic approach

- Find practical and systematic ways for handling non-crash (but non-adversarial) faults, by performing **semantic checks**



Given that checks are problem-specific, apply them to the infrastructure that supports large application base: **Pig/Hadoop**

Goals

- Deploy **transparently** to developer
- Perform **lightweight checks** trading cost for coverage to enable **opportunistic verification**
- Develop **fault model** to enable reasoning about effectiveness
- **Generalize** to other data-process systems

3. Developing semantic checks for Pig/Hadoop

Test whether various operators meets the following correctness requirements:

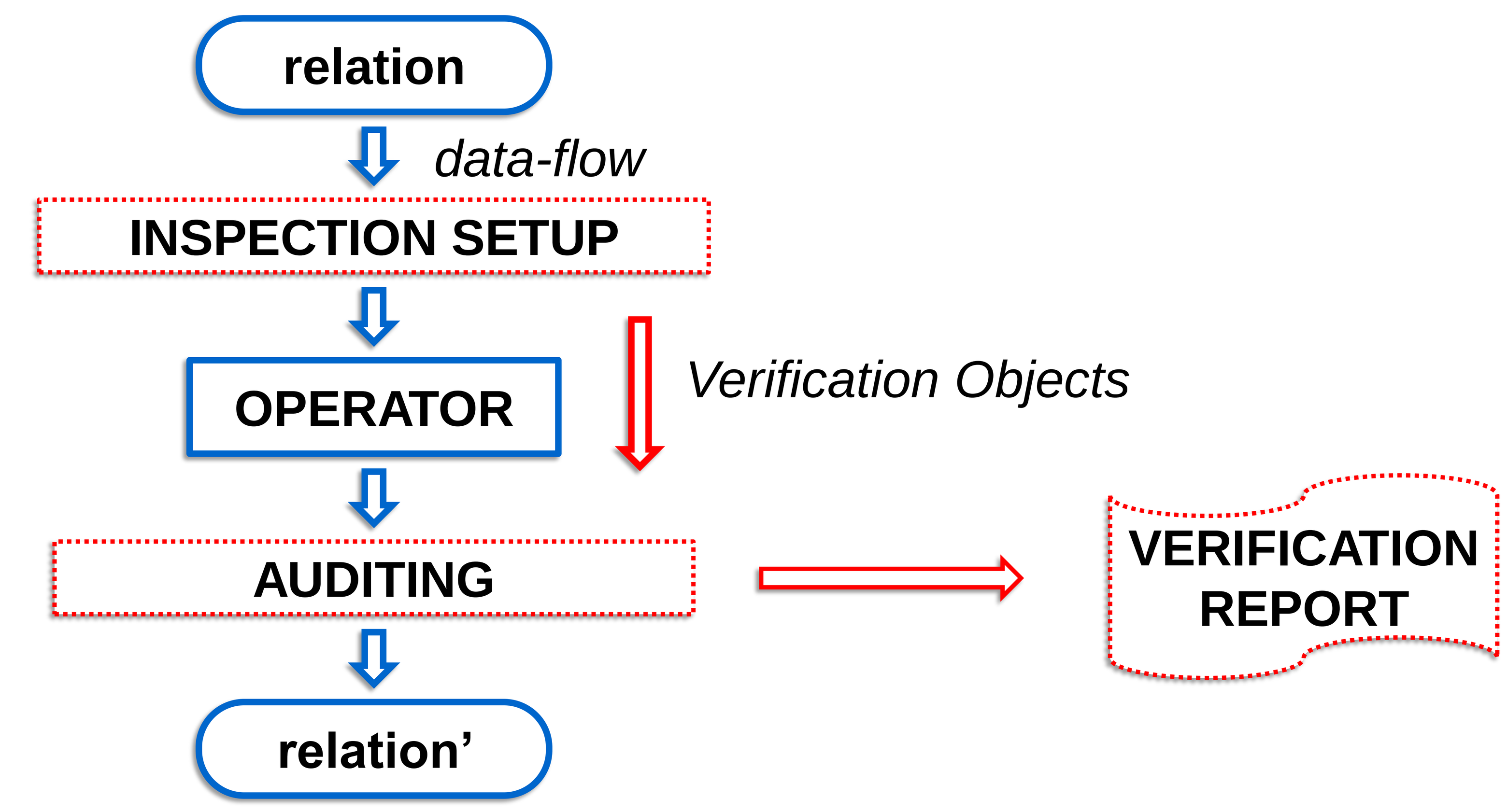
Integrity: output contains no corrupted or spurious records

Completeness: output contains all records that should be there

Goal is to develop effective techniques that check both properties while enabling trading cost for coverage

4. Example: Semantic check for Filter operator

- Build a set of verification objects (VOs) while scanning the data flowing into the operator
- Use these VOs to check for correctness while scanning data flowing out of the operator:



For input $\mathbf{i_1 \ldots i_n}$ and output $\mathbf{o_1 \ldots o_m}$, Filter check consists of:

Integrity: $\mathbf{o_j} \in i_1 \ldots i_n$ and $\mathbf{o_j}$ meets filter condition

Completeness: either $\mathbf{i_j} \in o_1 \ldots o_n$ or $\mathbf{i_j}$ does not meet filter condition

Opportunistic verification

Trade cost for coverage by performing spot checking

Efficient inclusion tests might employ Bloom filters as a VO:

- False positives in set inclusion imply a false negative in answer

5. Open challenges

How to amortize costly steps, e.g., Bloom filter creation?

- Attempt to **merge checks** for multiple operators, thereby only creating one Bloom filter per merged check

How can fault model capture less pessimistic assumptions?

- Consider fine-grained sub-computations (unit of fault)
- Assign a probability distribution to the faulty output
- Compute overall probability of checks failing

What guarantees are provided and are they sufficient?

How to handle extensibility mechanisms (user-defined functions)?

6. Final remarks

- Opens the opportunity to develop new ways to reason about non-crash faults
- Mechanism for handling non-crash faults in data center-scale computations
- Lightweight compared to Byzantine model
- Wide coverage of problems compared to crash model
- Tune cost for coverage according to resource availability

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