

# The Edge, the Cloud and the Supercomputer: Welcome to the Age of the Digital Continuum!

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Inria, Rennes

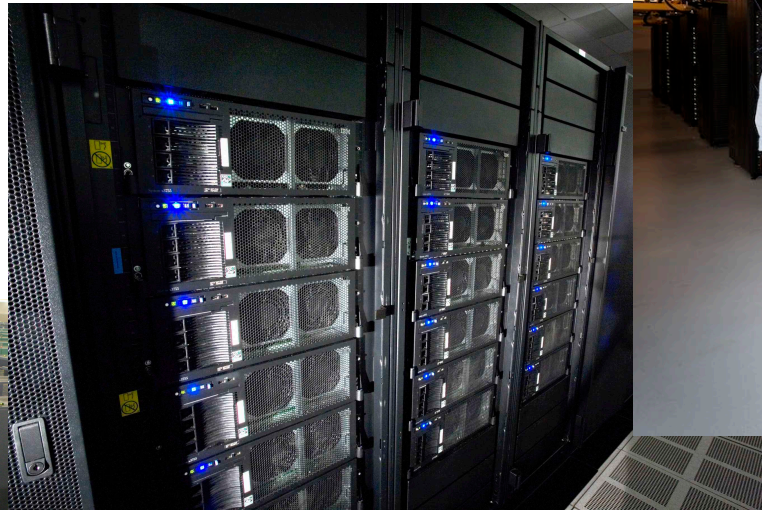


LIRIMA seminar  
13 May 2020

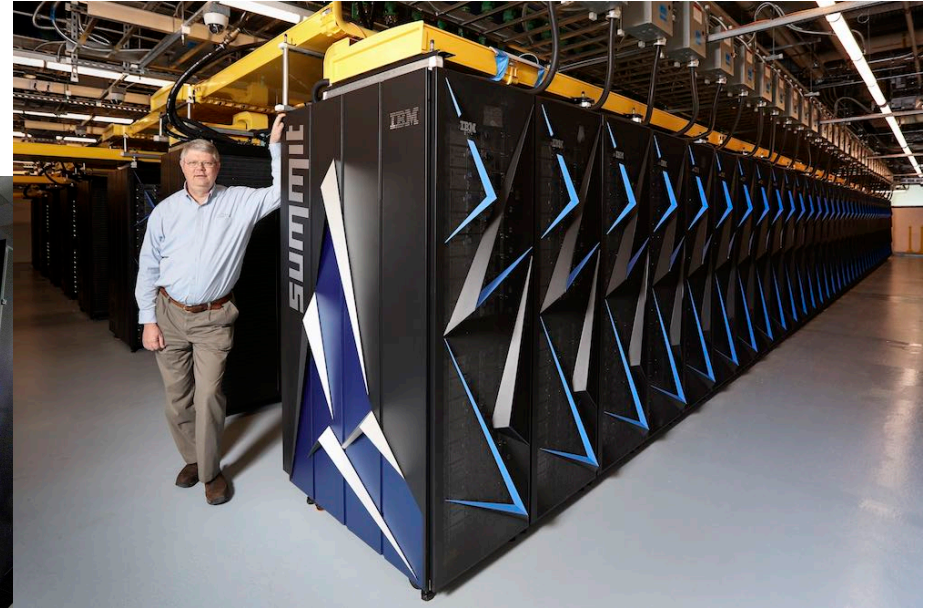
# The Supercomputer and the Race for Performance



2002 - Earth Simulator  
1 Teraflops ( $10^{12}$  flops)  
NEC, Japan



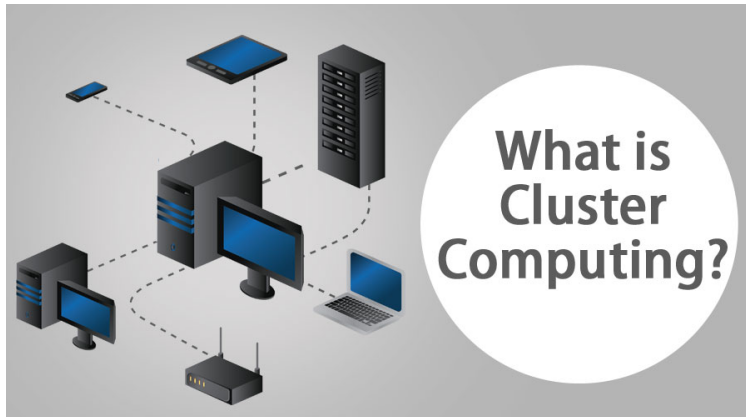
2008 - RoadRunner  
1 Petaflops ( $10^{15}$  flops)  
IBM, USA



Today - Summit  
200 Petaflops  
IBM, USA



# Democratizing Performance: Cluster Computing



Google Cluster in 1997



Google Cluster in 2011

# The Power Grid Concept



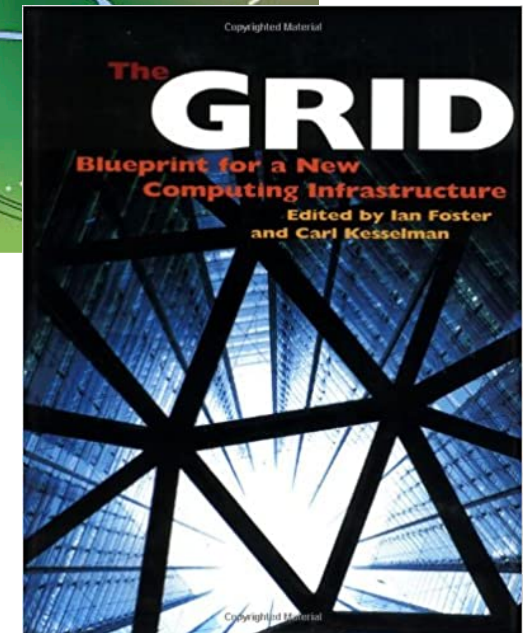
Distributing **electrical** power



# The Grid Computing Concept



Distributing **computing** power



# 2007: the Birth of Cloud Computing

**GOGRID** beta  
A ServePath Company  
877.9.GO.GRID  
1.415.869.7444  
Contact Us Login  
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How GoGrid Works! Pricing/Sign Up 24/7 Support Company Community

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IBM  
IBM Software Strategy Group

**IBM Google Announcement on Internet-Scale Computing ("Cloud Computing Model")**

Oct 8, 2007

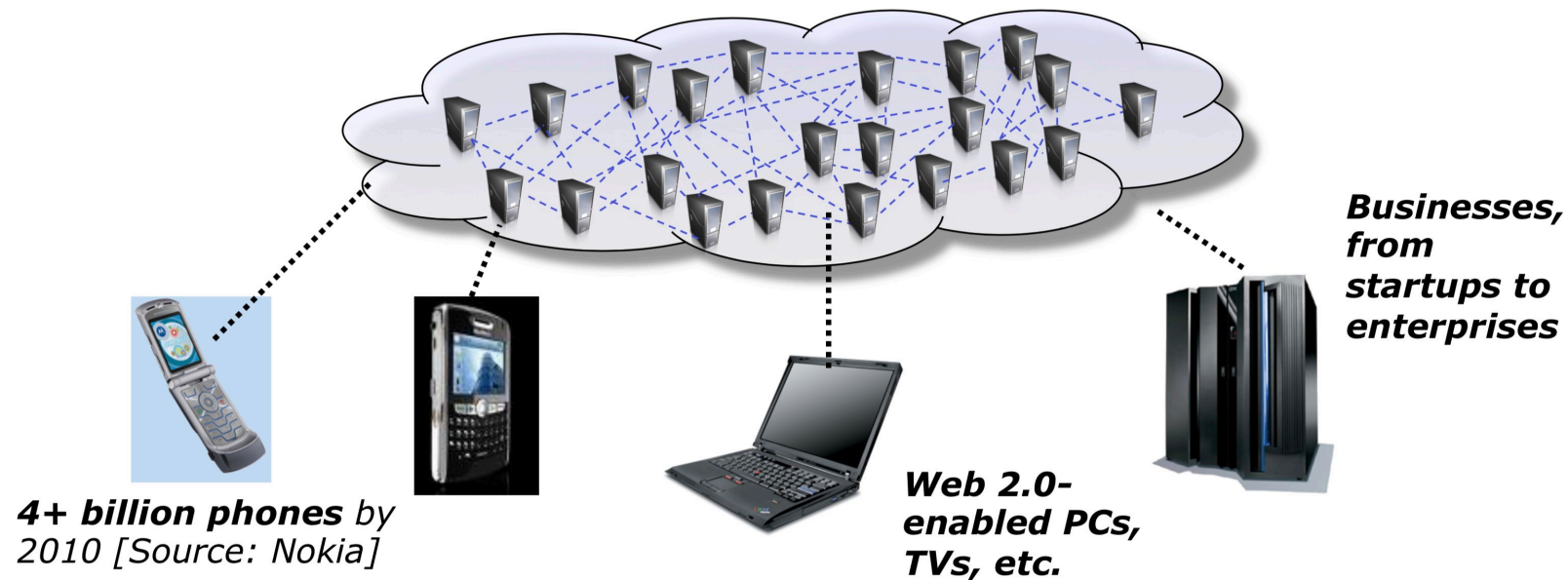
HiPODS

IBM Confidential until Oct 8, 2007 © 2007 IBM Corporation



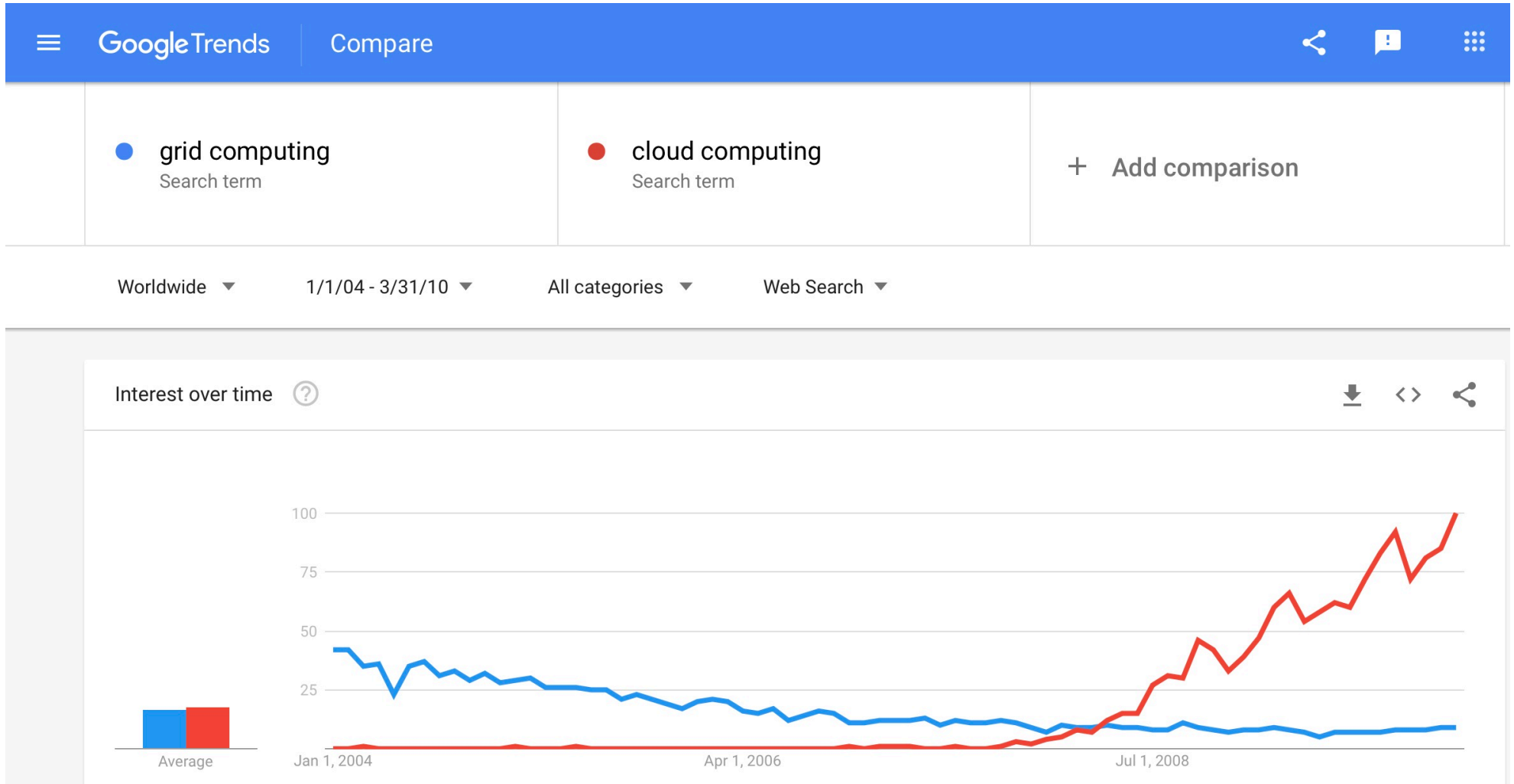
# What is Cloud Computing?

An emerging computing paradigm where data and services reside in massively scalable data centers and can be ubiquitously accessed from any connected devices over the internet.



Credit: IBM Corp.

# Beware the Cloud Hype!





# Cloud Datacenters





# The Way to the Cloud is Long...

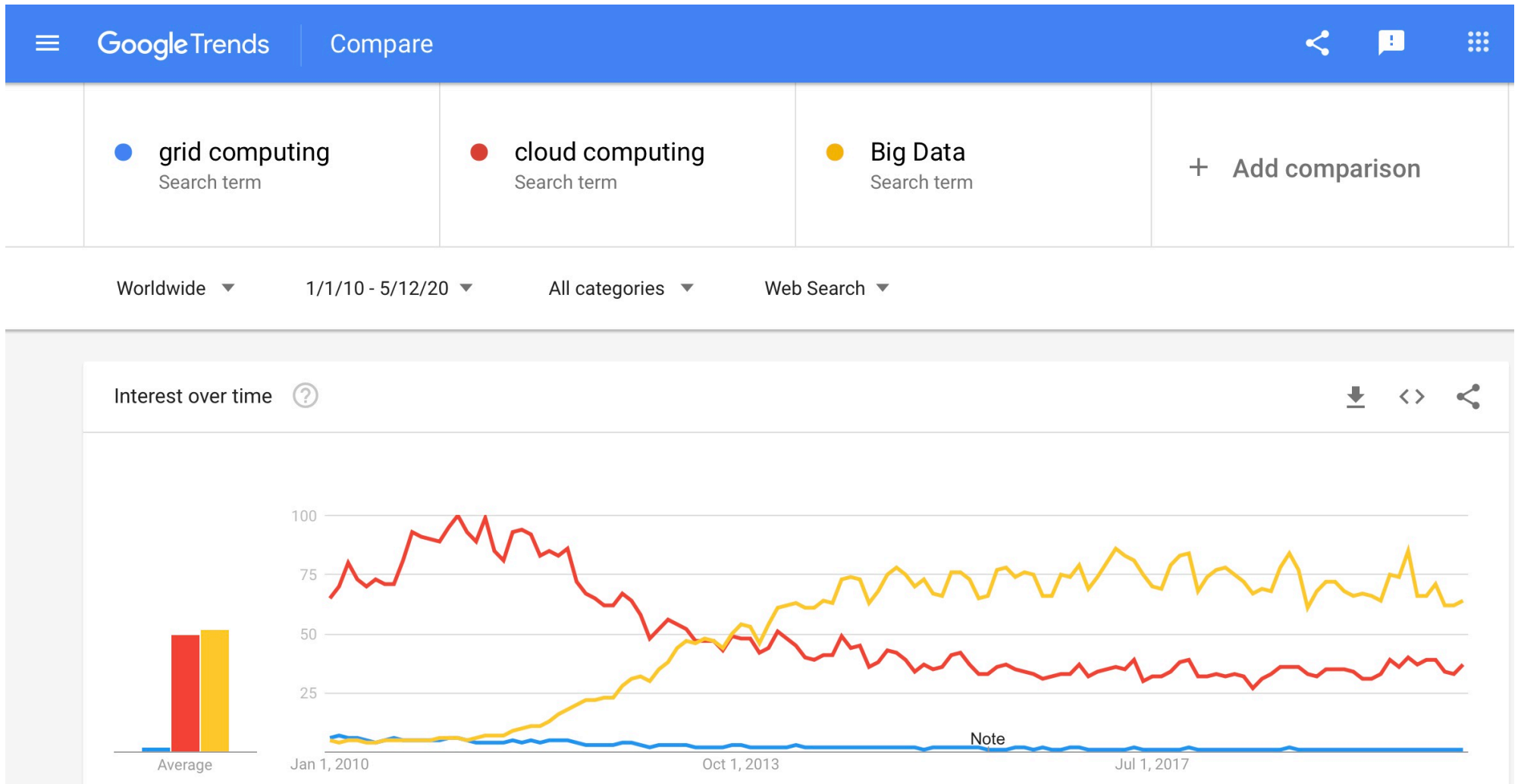




# Big Data Challenges: The Three Vs



# Beware the Big Data Hype!



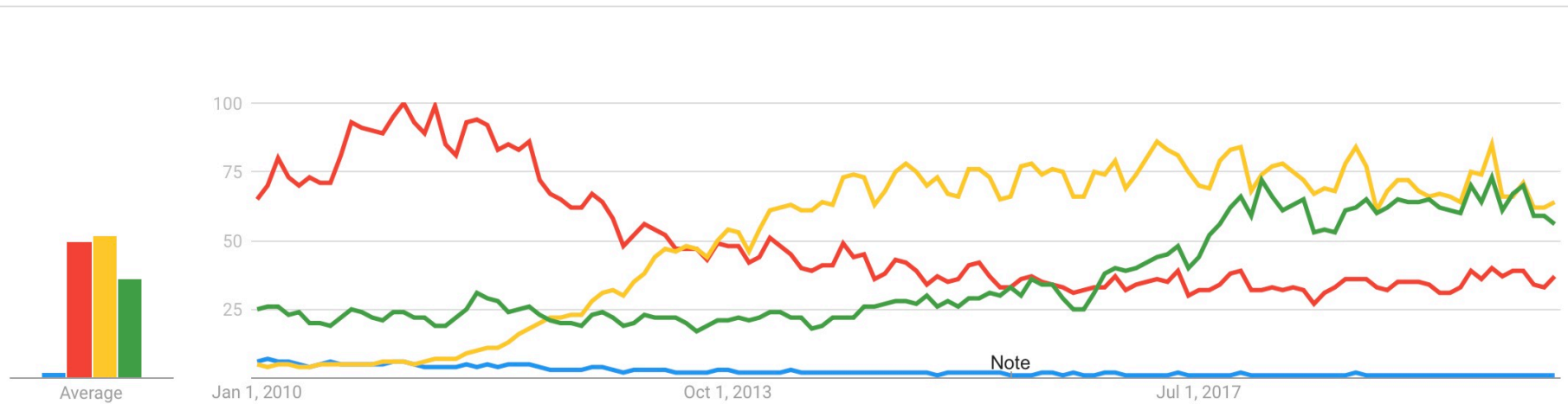
# What is the Next Hype?

Google Trends Compare

- grid computing Search term
- cloud computing Search term
- Big Data Search term
- artificial intelligence Search term**

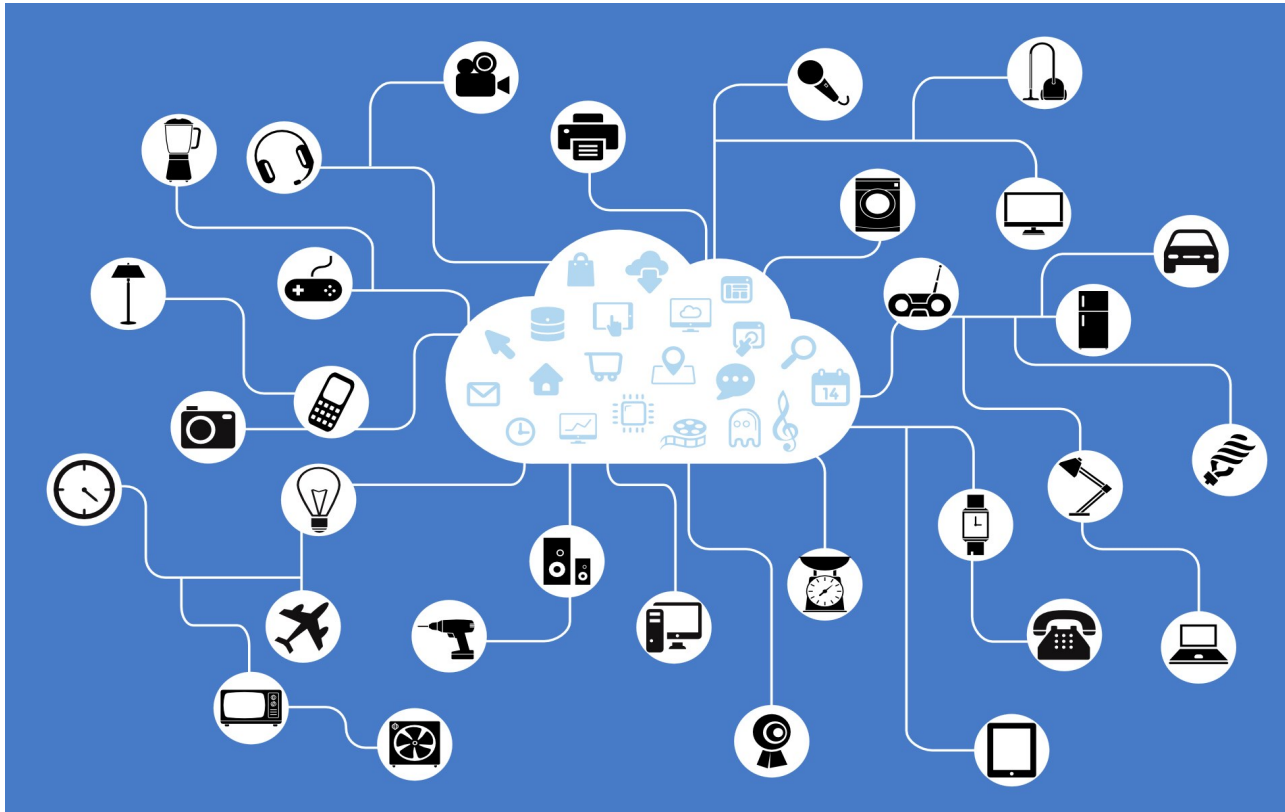
Worldwide 1/1/10 - 5/12/20 All categories Web Search

Interest over time





# Data Shifts to the Edge



*By 2022 Gartner predicts that 75% of enterprise-generated data will be created and processed outside of the data center and cloud infrastructures compared with 10% today.*

Source: Smarter with Gartner, What Edge Computing Means for Infrastructure and Operations, October 3, 2018  
Extract from: BullSequana Edge positioning paper (Atos)

# Sensors Everywhere: Towards Autonomous Driving





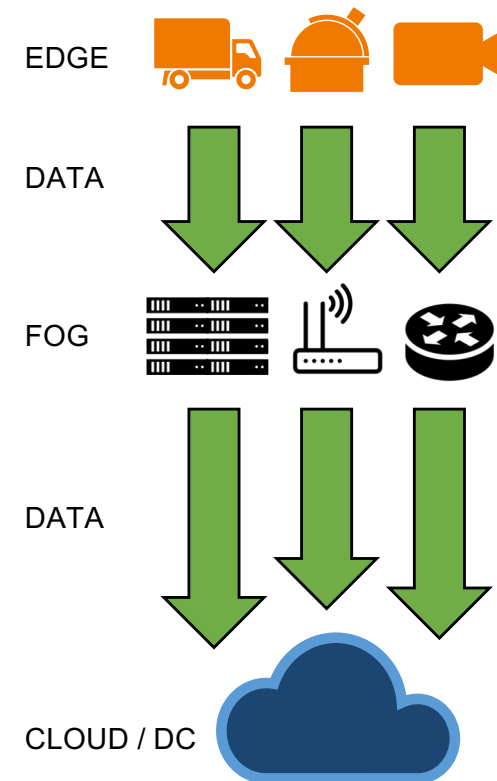
# Sensors Everywhere: Precision Agriculture



# Welcome to Edge Computing!

## Advantages

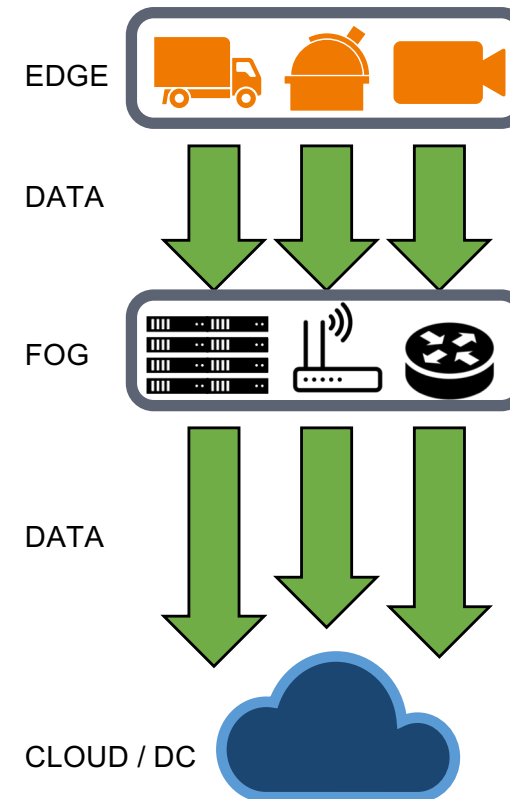
- Easier access to data
- Bandwidth saving
- Privacy
- High potential parallelism





# A Plethora of Edge Processing Tools

- Custom software
- Generic frameworks
  - Apache Edgent
  - Amazon Greengrass
  - Azure Stream Analytics
  - IBM Watson IoT
  - Intel IoT
  - Oracle Edge Analytics



# Edge Processing Tools Are Great! 😊

## Respond to local events in near real-time

AWS IoT Greengrass devices can act locally on the data they generate so they can respond quickly to local events,

## Simplified device programming with AWS Lambda

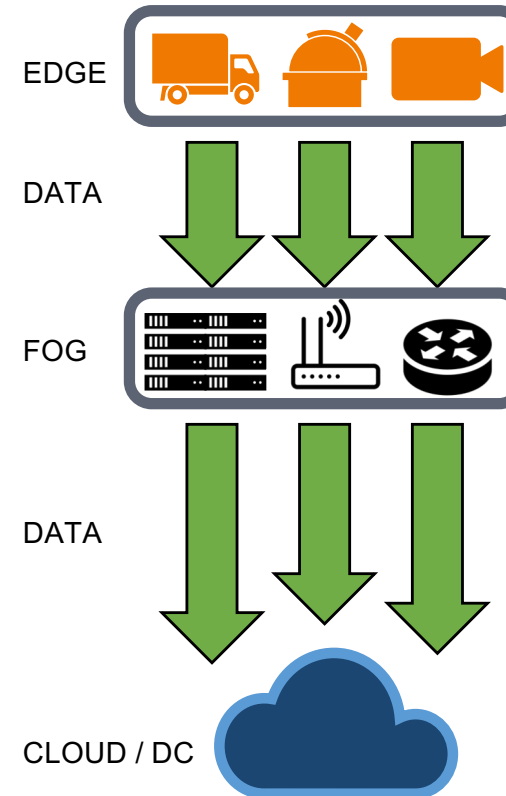
You can develop code in the cloud and then deploy it seamlessly to your devices with AWS Lambda. AWS IoT

## Capture data in real time

Process IoT data instantly to help identify valuable insights related to device behavior and operations in the field. Spot

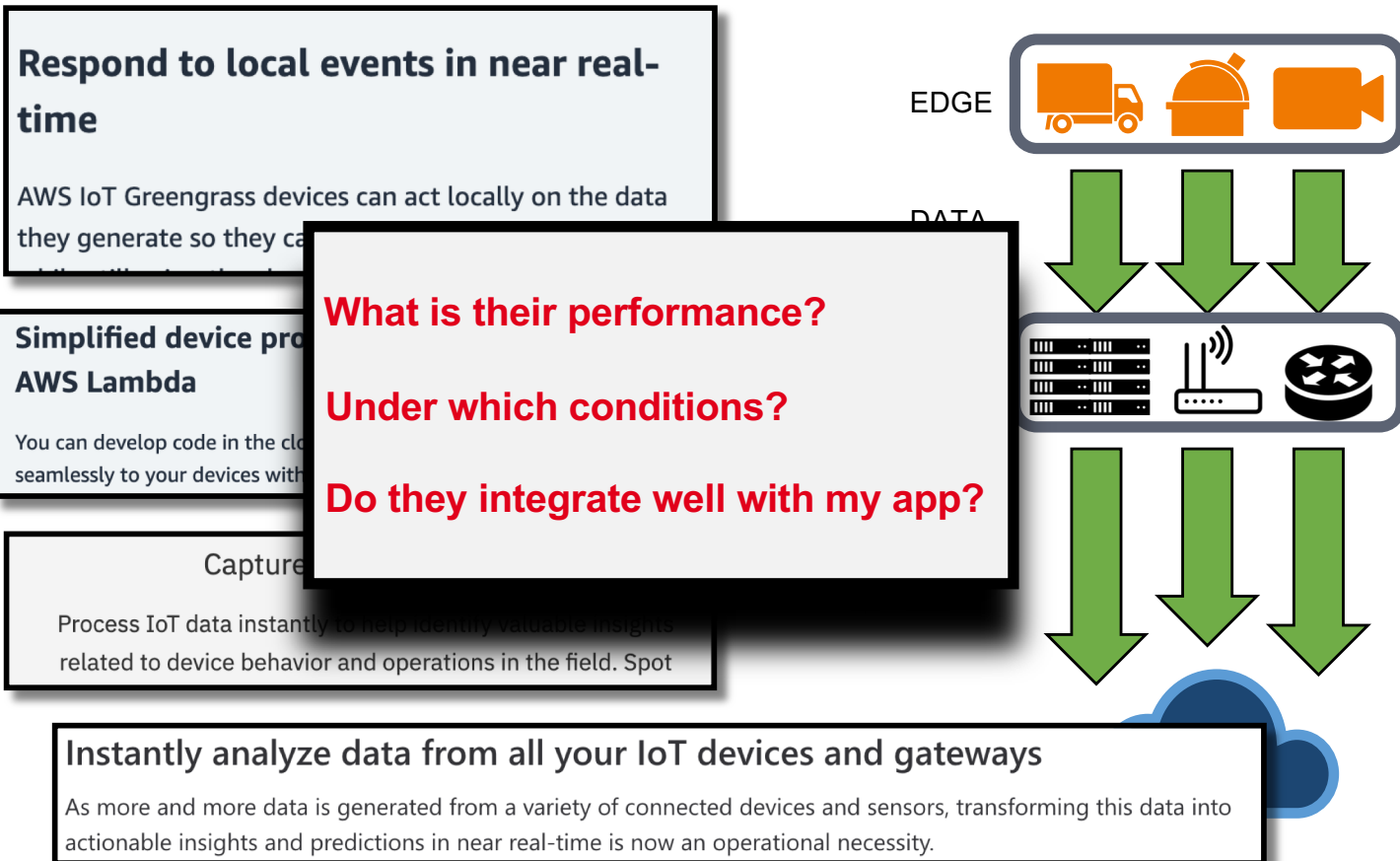
## Instantly analyze data from all your IoT devices and gateways

As more and more data is generated from a variety of connected devices and sensors, transforming this data into actionable insights and predictions in near real-time is now an operational necessity.



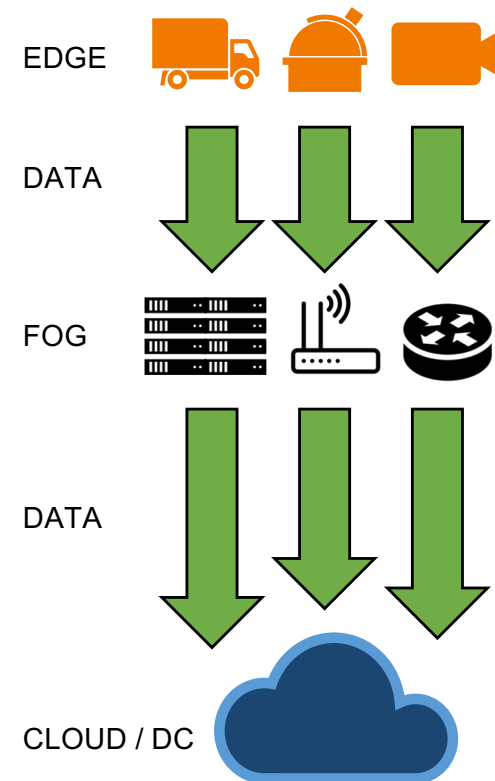


# How Great?



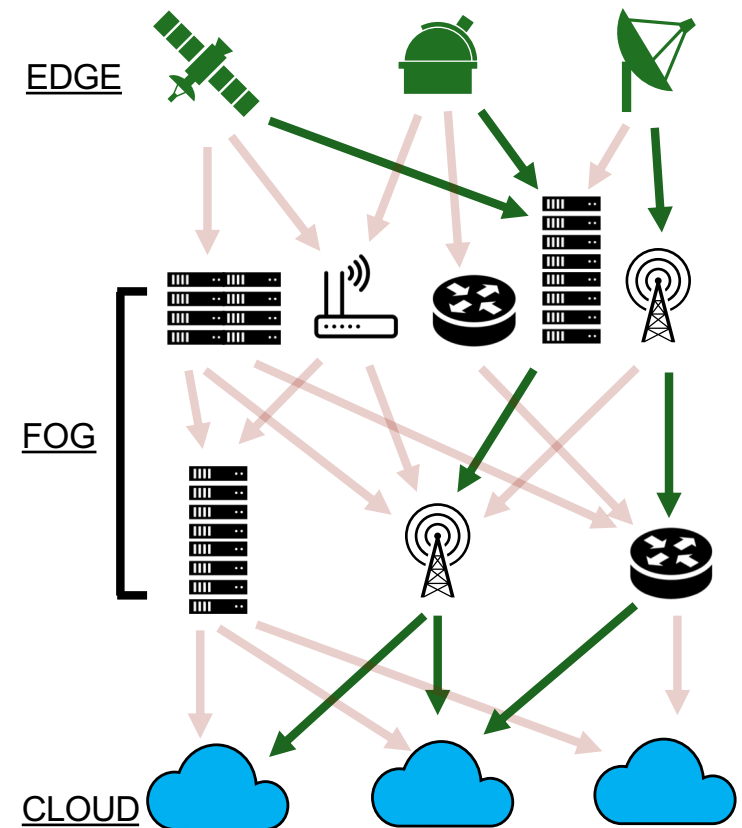
# We Need Benchmarking!

Goal: **Understand** performance



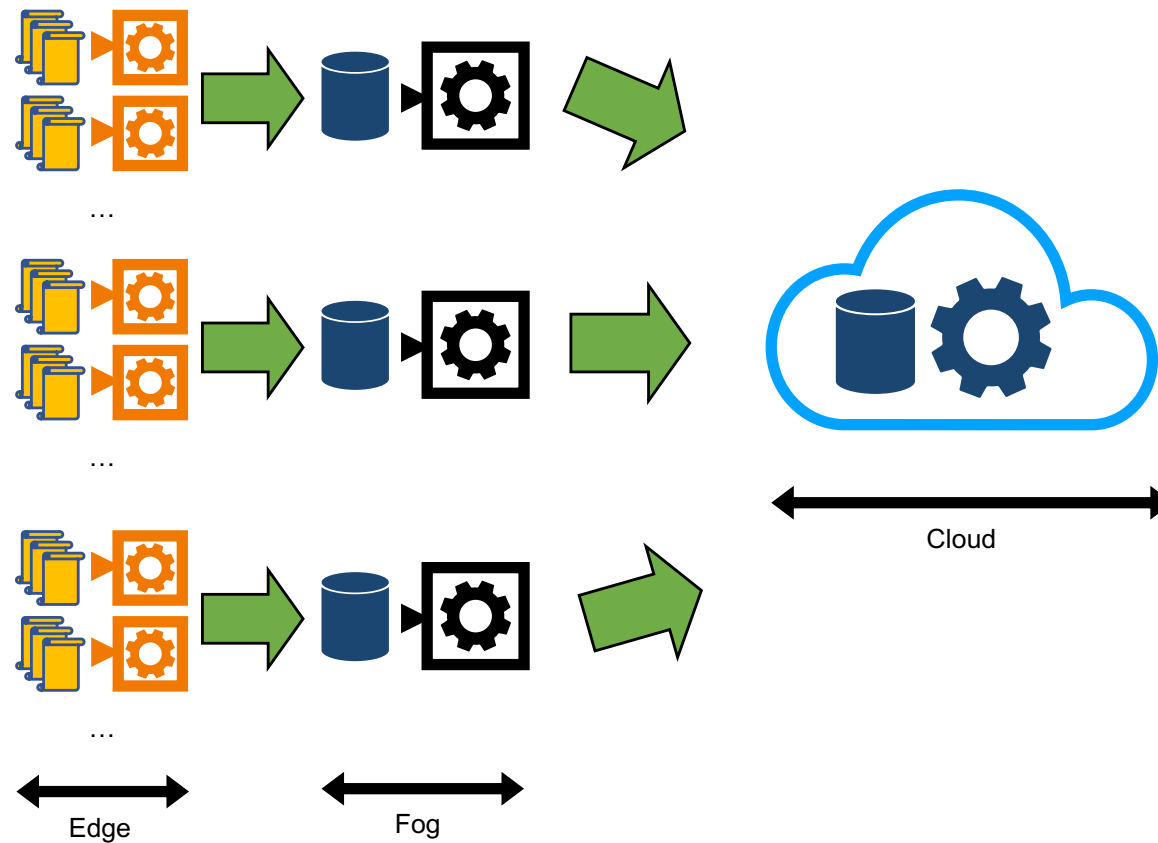
# Benchmarking in a Hybrid World: Questions

- ❑ Are the **cost models** precise?
  - ❑ What is the impact of **networking** on the performance?
  - ❑ How do my algorithms react to **real-time** scenarios?
  - ❑ How does my hybrid approach **compare** to a fully centralized solution?
  - ❑ **Viability** on different infrastructure configurations
  - ❑ What methodology for **reproducible** experiments?
- 
- ❑ SILVA, P., COSTAN A. and ANTONIU, G., Towards a Methodology for Benchmarking Edge Processing Frameworks. 1st Workshop on Parallel AI and Systems for the Edge (PAISE workshop collocated with IPDPS 2019).

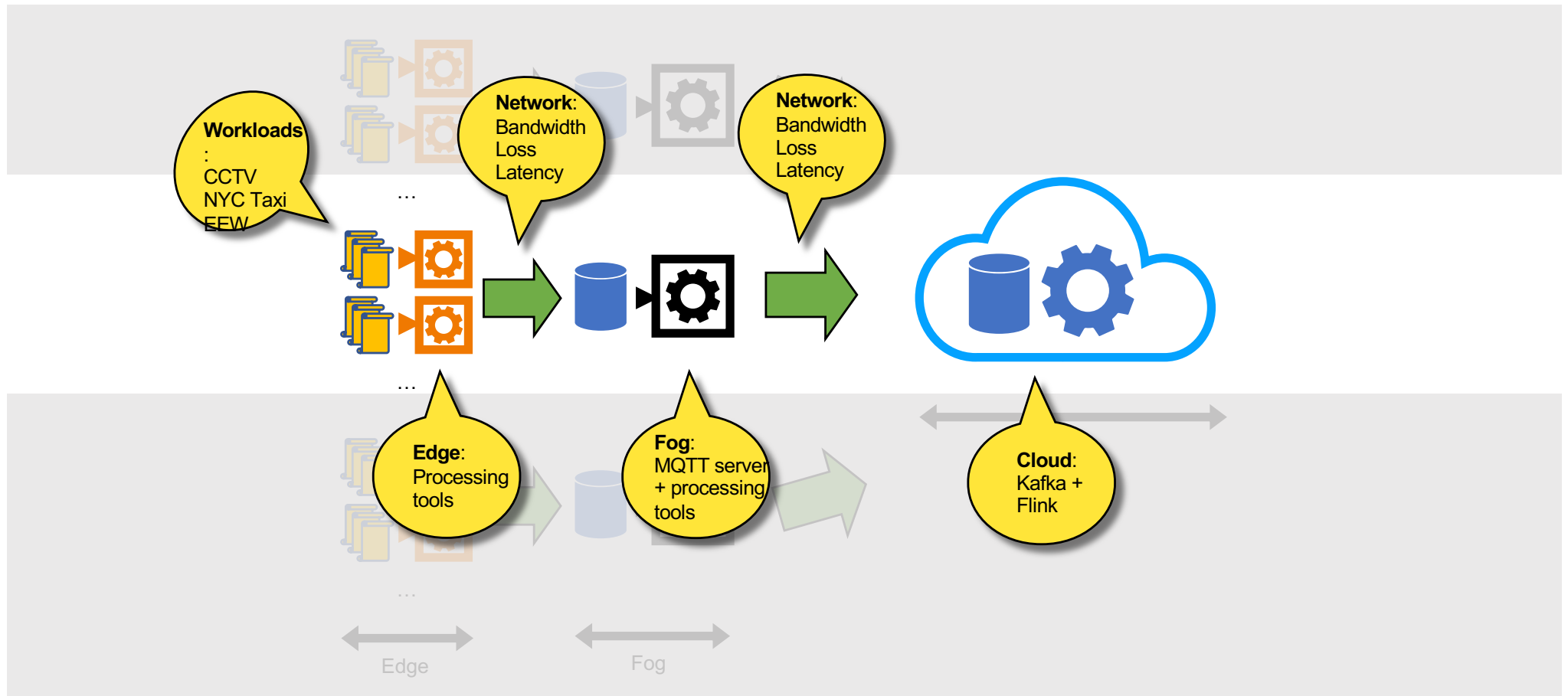




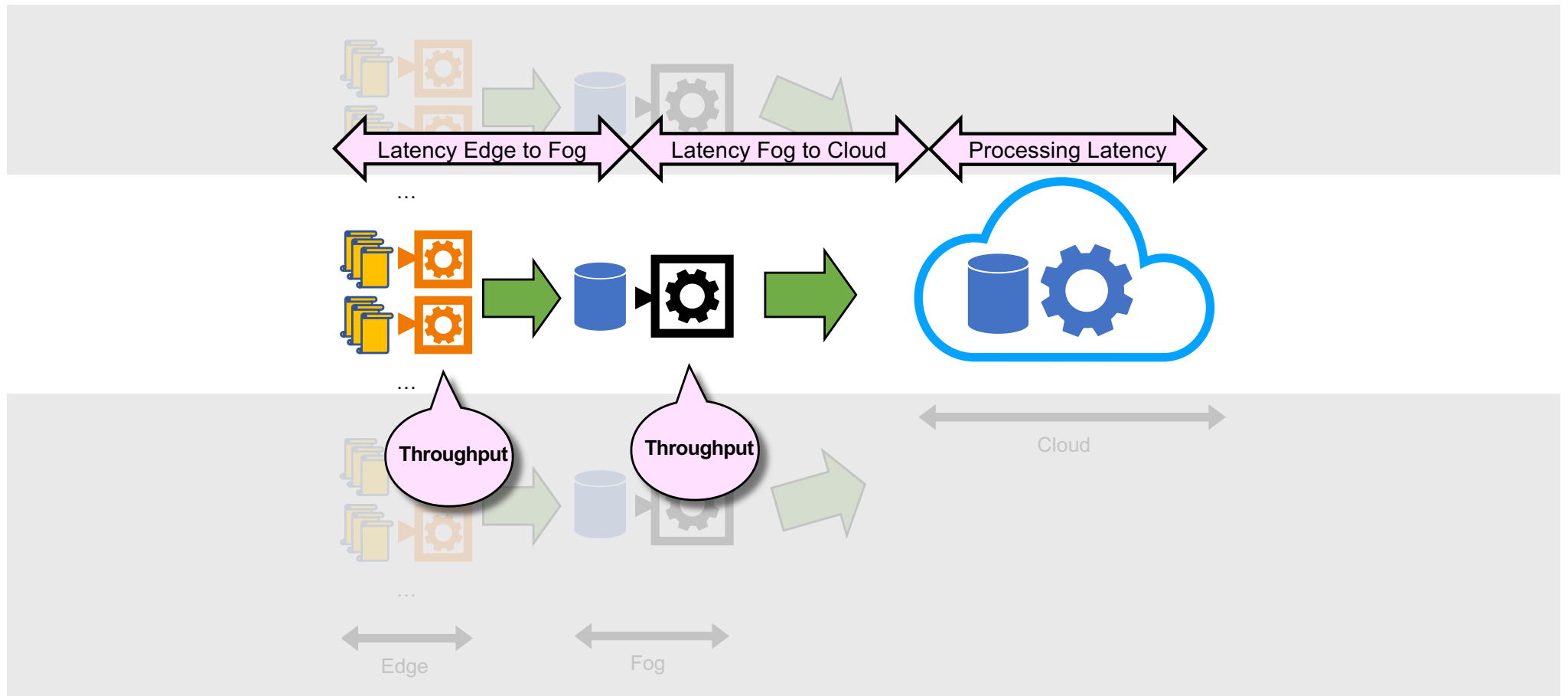
# Benchmarking Hybrid Processing: Zoom



# Benchmarking Hybrid Processing: Parameters



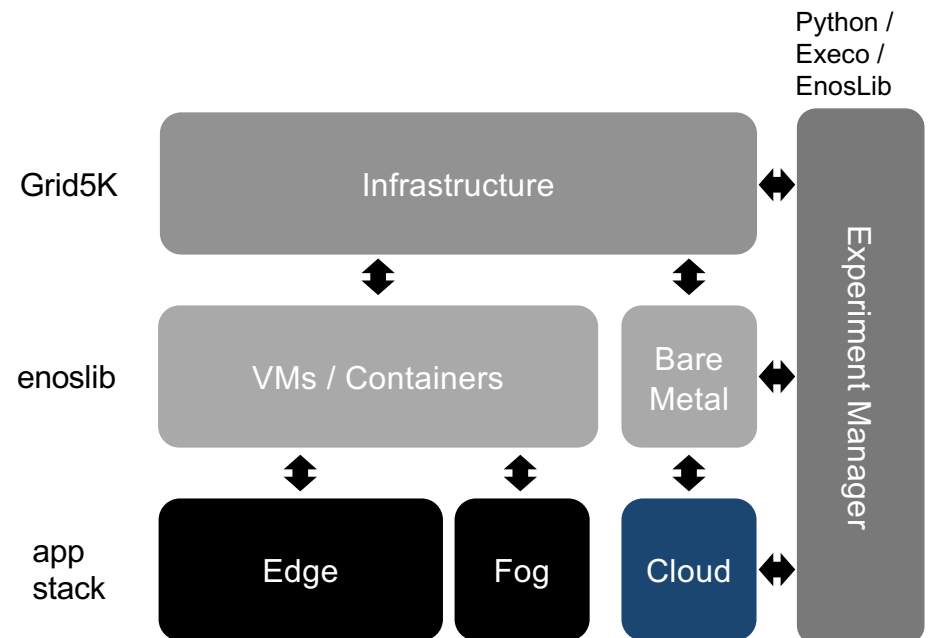
# Benchmarking Hybrid Processing: Metrics





# Benchmarking Platform: Implementation

- **Experiment manager**
  - Configures the infrastructure
  - Deploys frameworks/tools
  - Deploys applications and manages their executions
  - Monitors resource usage
  - Gathers metrics and logs
- **Edge+Fog+Cloud processing management**
  - Metric generation, configuration, connection



# An Example of Application: Earthquake Early Warning Systems

## Earthquakes

Large ground motions which cause substantial loss and damage to the environment across areas

spanning hundreds of kilometers from their origins (tsunamis, fires, landslides)

Earthquake Early Warning (EEW)

## Objectives

- > Automatically detect and characterize earthquakes as they happen
- > Deliver alerts before the ground motion actually reaches sensitive areas

FAUVEL, K. ; BALOUEK-THOMERT, D. ; MELGAR, D. ; SILVA, P., SIMONET, A. ; ANTONIU G. ; COSTAN, A ; MASSON, V ; PARASHAR, M. ; RODERO, I. ; TERMIER, A. A Distributed Multi-Sensor Machine Learning Approach to Earthquake Early Warning. AAAI 2020, February, New York. **Outstanding Paper Award for Social Impact.**

# EEW - Current Challenges

## Earthquake Category vs Sensors

Two categories of earthquakes with damaging potential

### Large Earthquakes

( $6 \leq$  magnitude, Richter scale)

- ✗ Seismometers: saturation issue
- ✓ GPS Stations

### Medium Earthquakes

( $5 \leq$  magnitude  $< 6$ , Richter scale)

- ✓ Seismometers
- ✗ GPS Stations: noise

## Response Time and Robustness

- ✗ Traditional centralized approach impractical
- > **Large number of sensors with high frequency data streams**
- > **Sensors are geographically distributed**



# EEW - Our Positioning

## Data

More and more data **available** from sensors (e.g. seismometers, GPS stations)

## Solutions

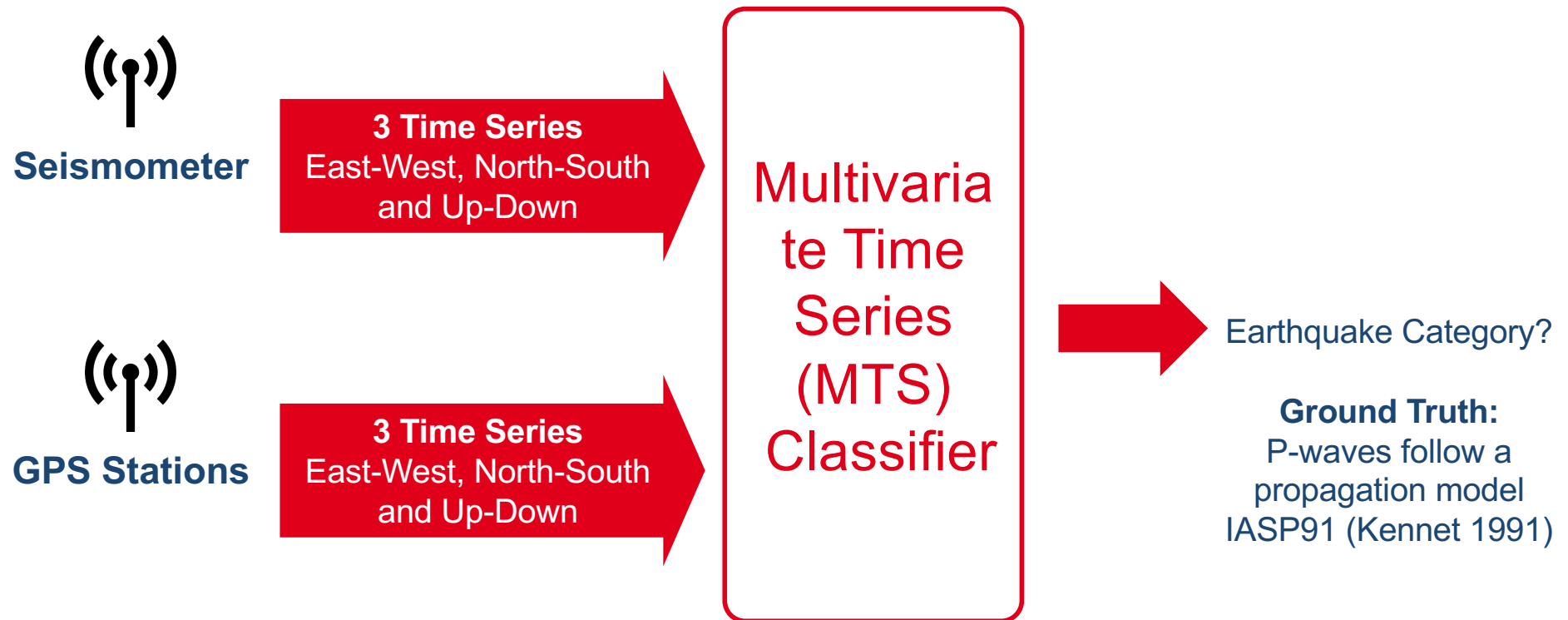
EEW solutions exist (Yoon et al. 2015; Li et al. 2018; Perol, Gharbi, and Denolle 2018)

- > No approach combining seismometers and GPS stations
- > No distributed solution

## POSITIONING

Integrating two **complementary** types of **sensors** in real-time based on a **distributed hybrid infrastructure** to cover the **whole spectrum** of potentially damaging earthquakes

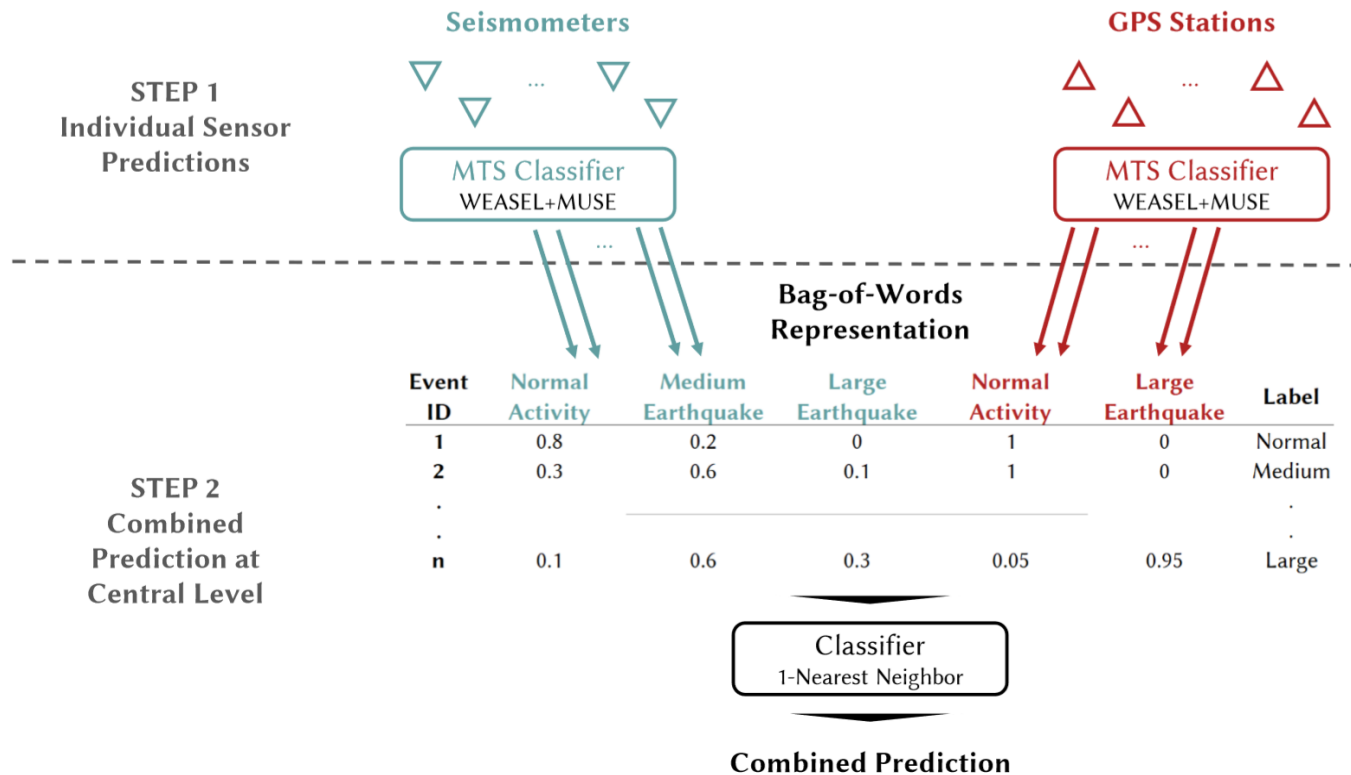
# Supervised Learning Problem



# Our Machine Learning Approach

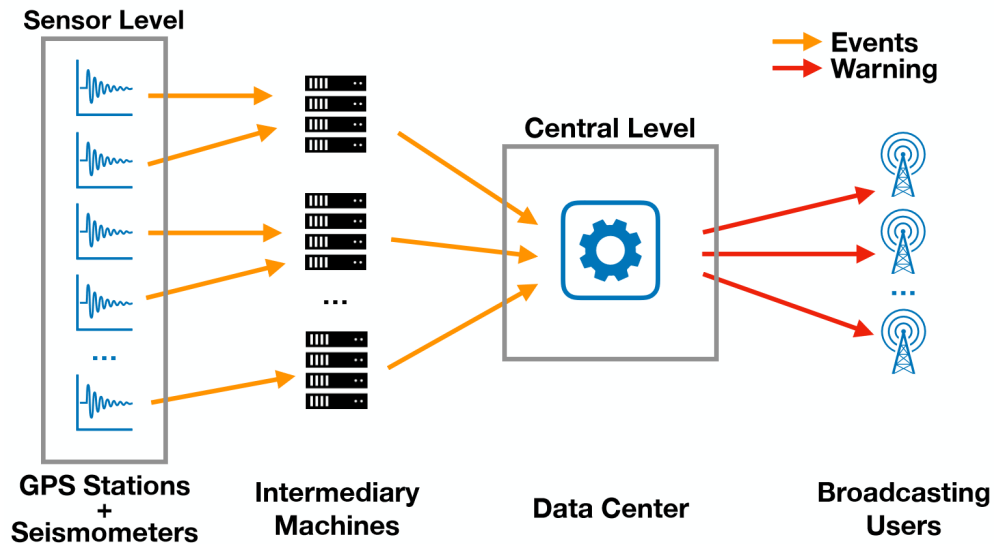
## Distributed Multi-Sensor Earthquake Early Warning (DMSEEW)

### A New Stacking Ensemble Method





# Distributed, Hybrid Infrastructure

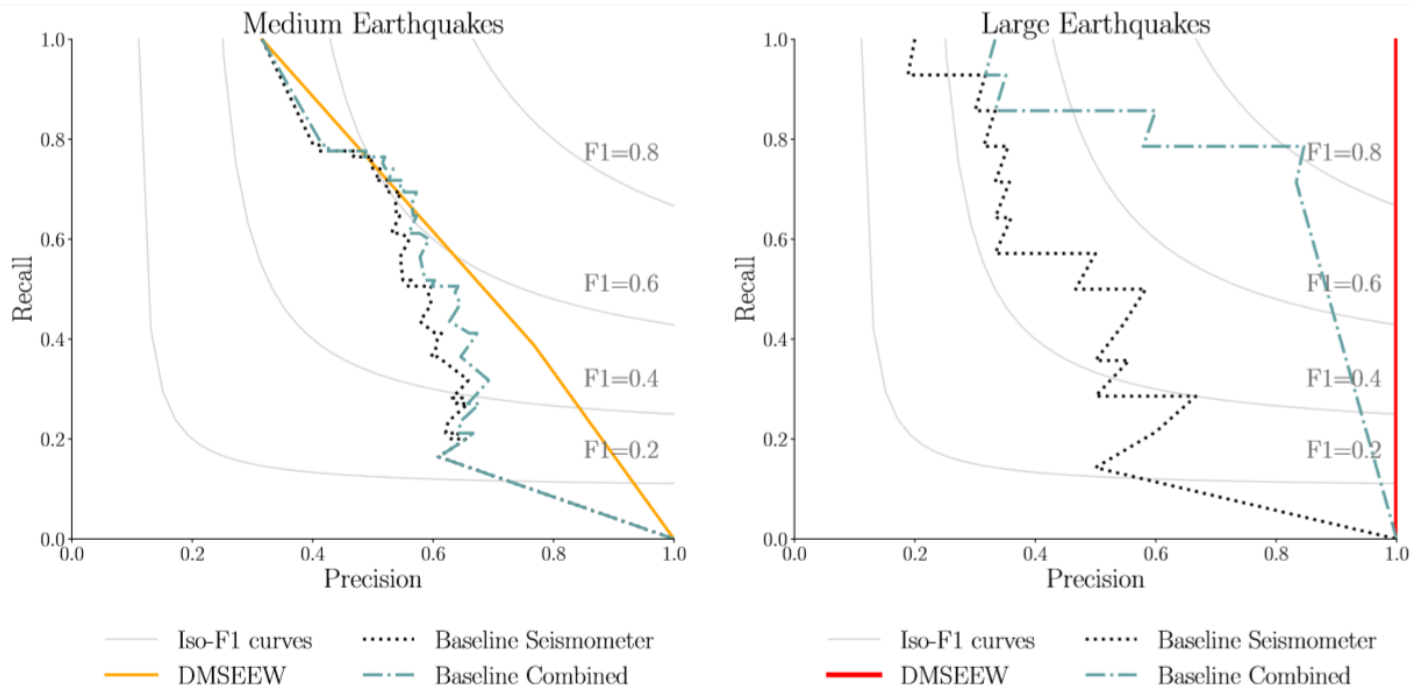


Sensor devices with computing capabilities

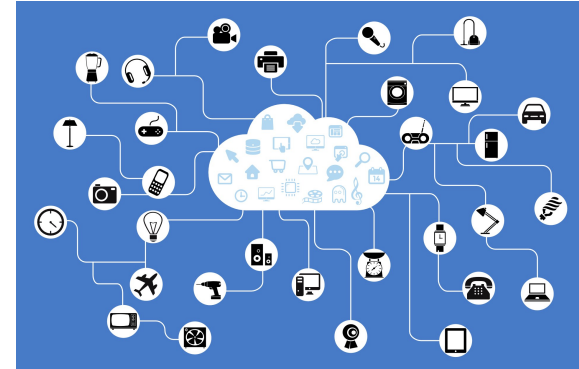
- ✓ Reduce the amount of data over the network
- ✓ Robustness in case of partial infrastructure failures

Edge + Cloud Computing

# DMSEEW Evaluation

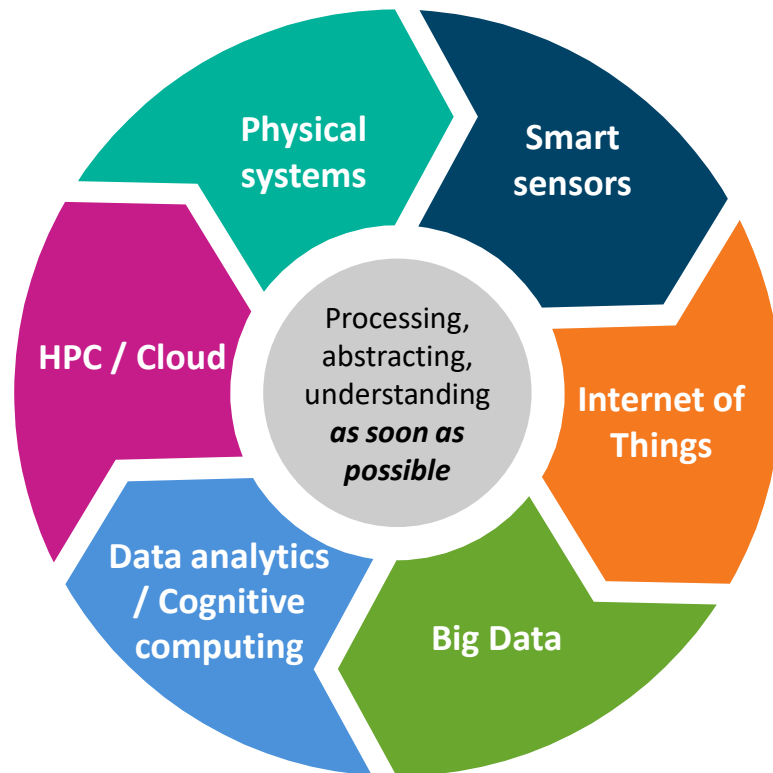


- ✓ DMSEEW **outperforms both** seismometer only and combined **baselines**
- ✓ DMSEEW detects **all large earthquakes without false alert**
- > Geographically distributed infrastructure
  - **Reduce the volume of data** transmitted in the network
  - **Increase the robustness** of the EEW system



**Is this a directional evolution?**

# Welcome to the Age of the Digital Continuum!



Enabling Intelligent data processing at the edge:

- Fog computing
- Edge computing
- Stream analytics

Transforming data into information as soon as possible

Collaboration between edge devices and the HPC/cloud ensuring:

- Data security and Privacy
  - Lower bandwidth
  - Better use of HPC/Cloud
- creating a continuous flow





# Mapping “Extremes’ prediction in the Digital Continuum” to the loop

Cyber-physical entanglement of real-time, digital twin of Earth system, optimal information of user-specific information on demand and physical systems in impact areas: energy, water, health, law

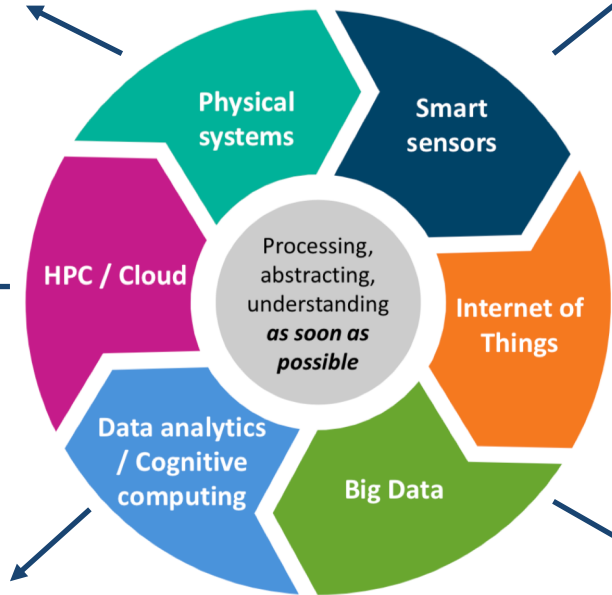
Smart sensors in mobile phones, cars, wind farms, agriculture farms, cities etc. for weather and air quality

Extreme-scale computing to generate digital twin

IoT for accessing relevant data & IoT for disseminating user specific information

Machine learning for information extraction, product tailoring, surrogate modelling

Extreme-scale data collection-processing-dissemination on tight schedules



Novel  
Emerging  
Established

# Thank you!

Contact: [gabriel.antoniu@inria.fr](mailto:gabriel.antoniu@inria.fr)

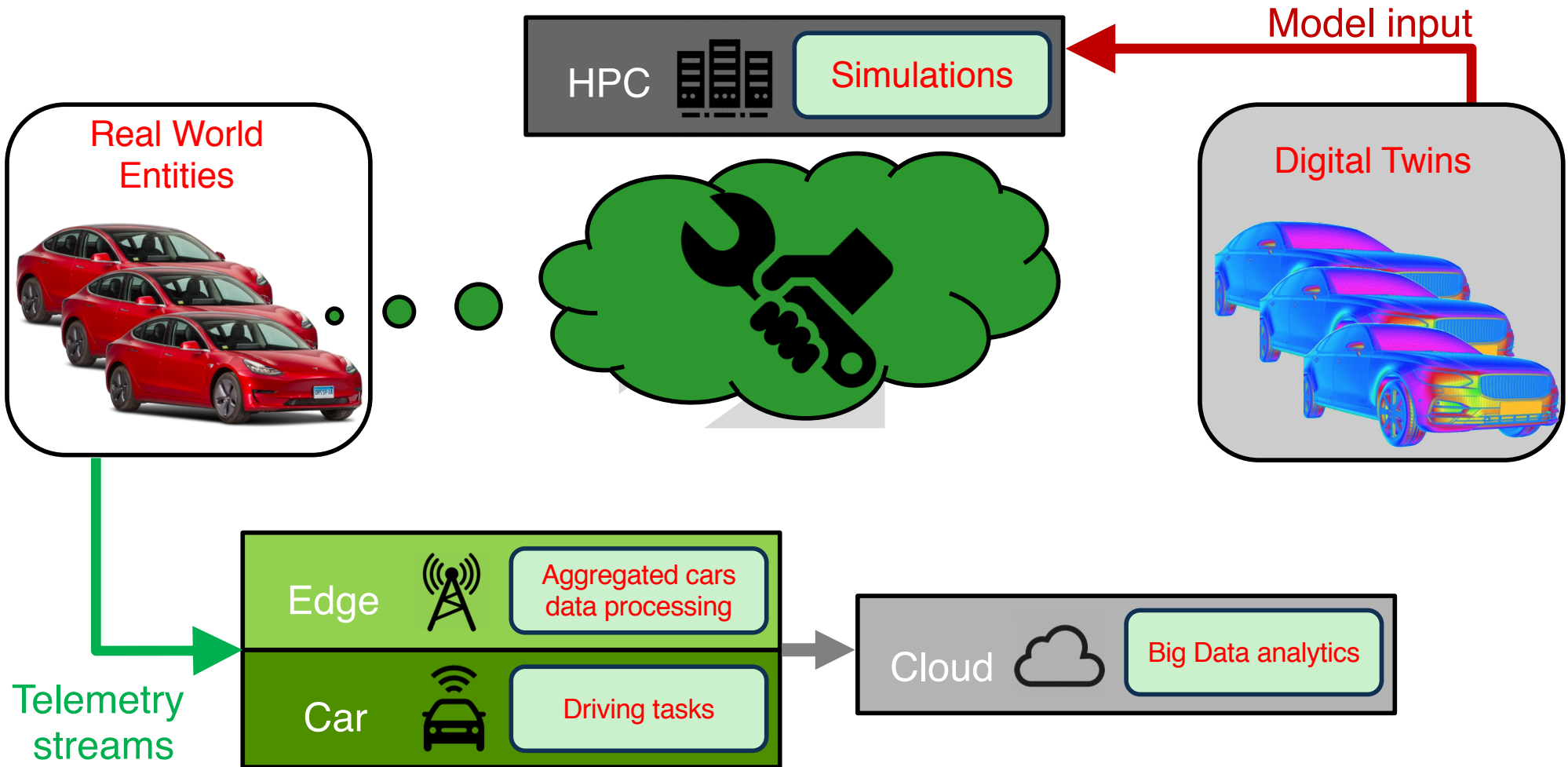


**BACKUP SLIDES**

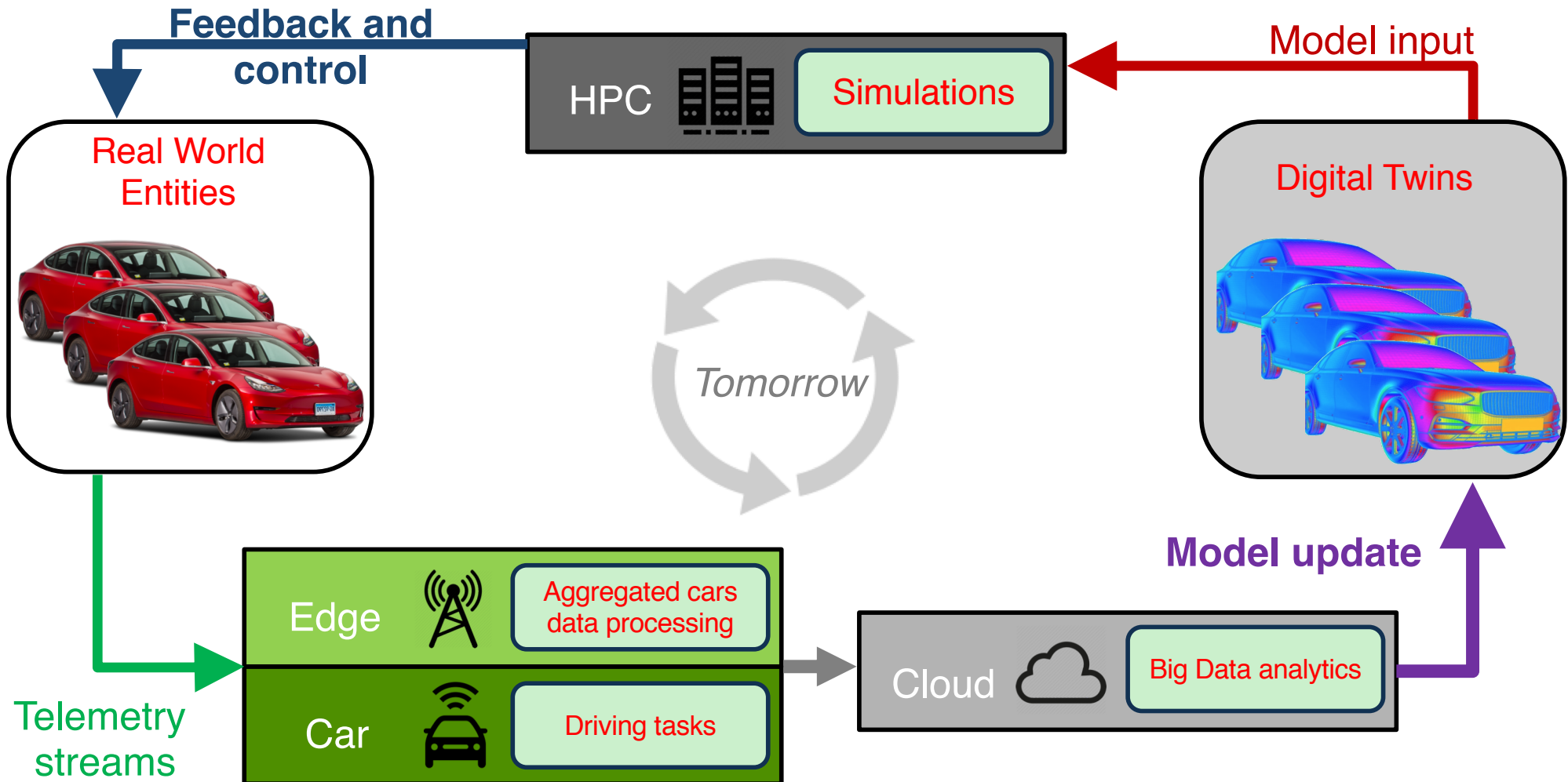
*Inria*

INVENTEURS DU MONDE NUMÉRIQUE

# Scenario: Digital Twins TODAY

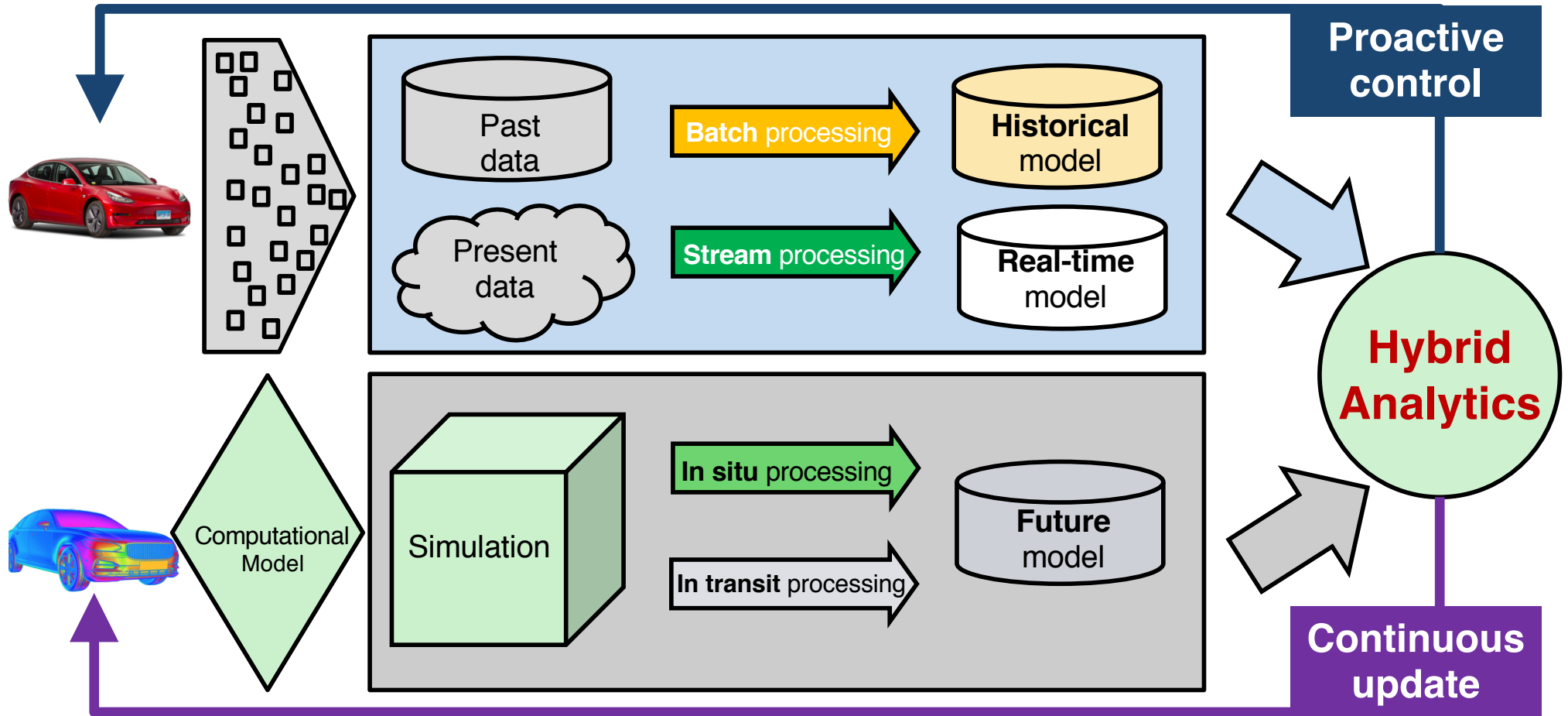


# Scenario: Digital Twins TOMORROW

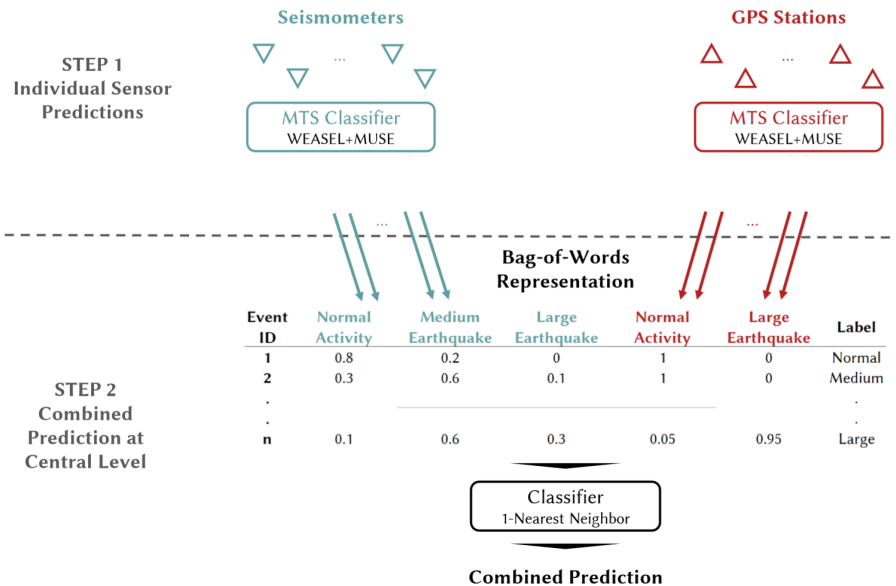




# Our vision: Enabling Hybrid Analytics Through Unified Data Processing



# Experiments



> **Metric:** Accuracy

> **Performance:** 3-Fold Cross-Validation

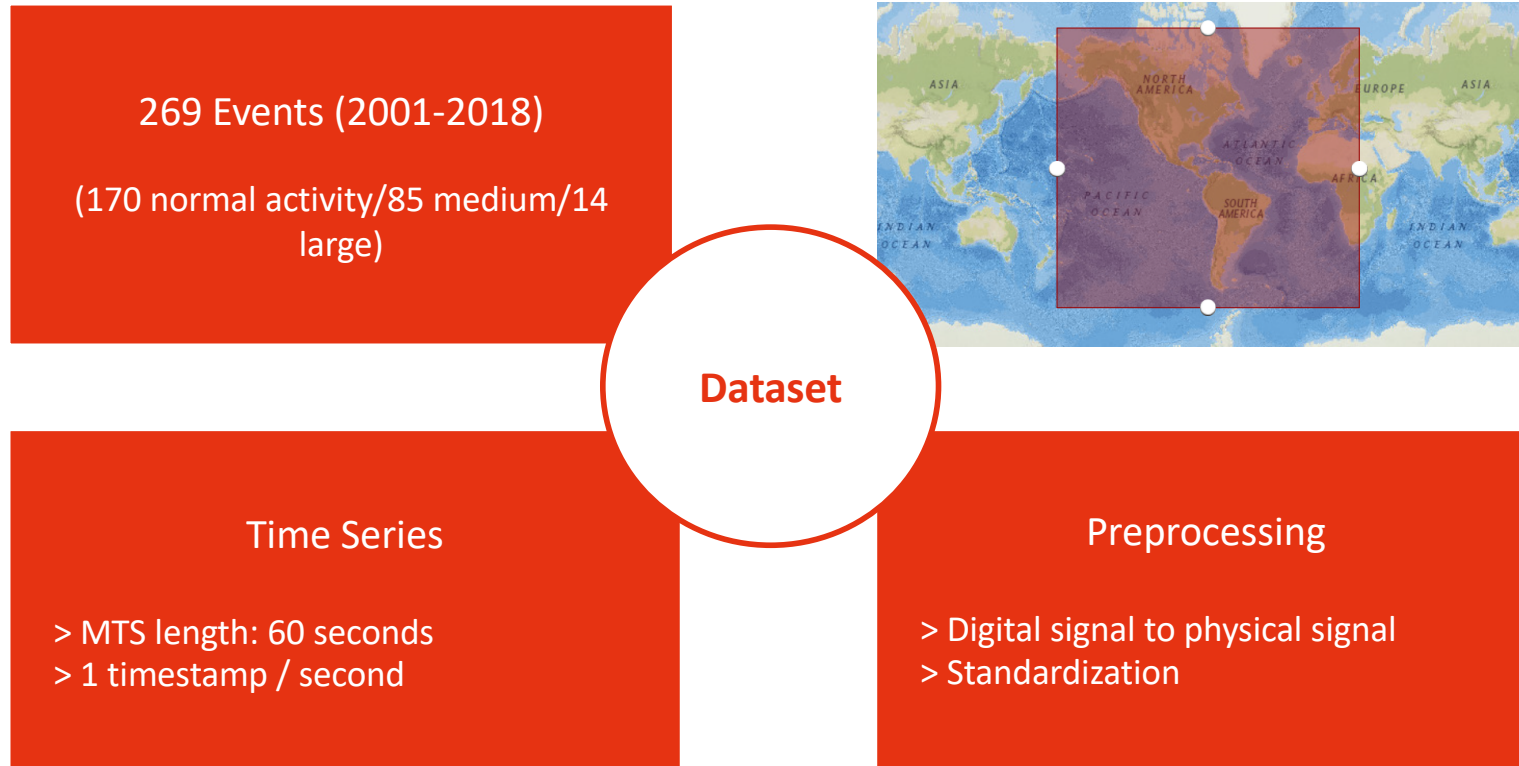
> **Step 1 - MTS Classifiers:** DTW<sub>D</sub>, DTW<sub>I</sub>, MLSTM-FCN, WEASEL+MUSE

> **Step 2 - Classifiers:** k-NN, Elastic Net, SVM, Random Forest, Extreme Gradient Boosting

> **Benchmark:**

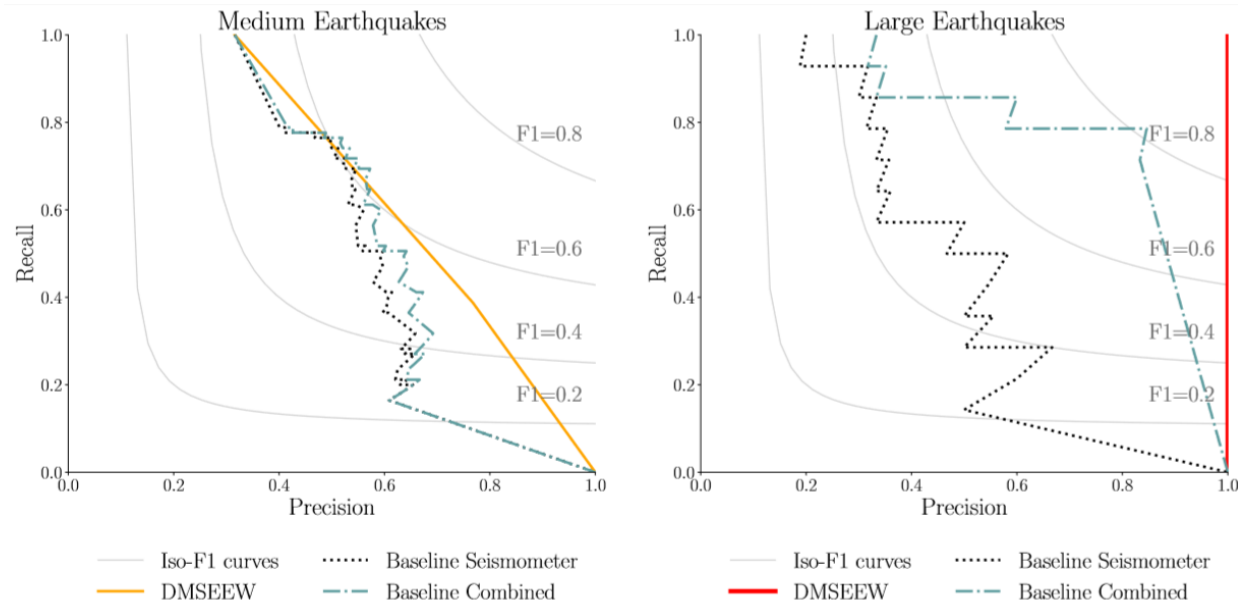
- Traditional Seismometer Only
- Combined Sensors with the Rule of Relative Strength

# Experiments



<sup>1</sup> [https://figshare.com/articles/Earthquake\\_Early\\_Warning\\_Dataset/9758555](https://figshare.com/articles/Earthquake_Early_Warning_Dataset/9758555)

# Results



- ✓ DMSEEW **outperforms both** seismometer only and combined **baselines**
- ✓ DMSEEW detects **all large earthquakes without false alert**

# Conclusion

- > **Performance improvement** of DMSEEW on the detection of **earthquakes with damaging potential** / traditional seismometer only and rule based combined approaches
  
- > Detection of **all large earthquakes without false alerts**
  
- > Geographically distributed infrastructure
  - **Reduce the volume of data** transmitted in the network
  - **Increase the robustness** of the EEW system
  
- > **Perspectives:**
  - Simulate different scenarios in an existing EEW execution platform to evaluate DMSEEW response time and robustness
  - Extend the evaluation of DMSEEW on the other main seismic network (Japanese NIED)



# Hybrid Processing Architecture

