

Computing for the Future of the Planet

Andy Hopper





Optimal Digital
Infrastructure



Sense and Optimise



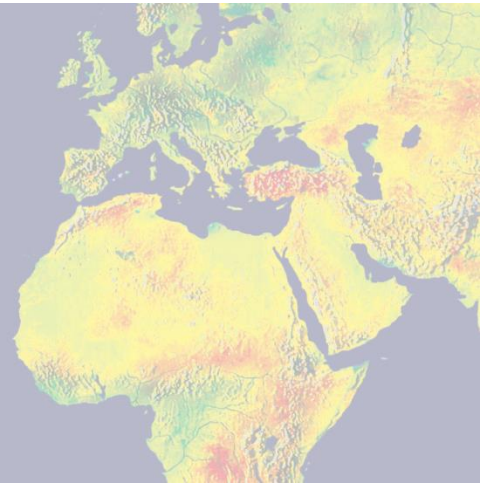
Predict React Automate

Physical to Digital

Framework

1. Optimal Digital Infrastructure – “Green Computing”
2. Sense and Optimise – “Computing for Green”
3. Predict, React, Automate - “Guaranteed Computing”
4. Digital Alternatives to Physical Activities – “Physical to Digital”





Green Computing

Computing for Green

Guaranteed Computing

Physical to Digital

1 – Green Computing

- Data centre design
- Energy-proportional processing, networking, storage
- Direct use of renewable energy
- Use of surplus renewable energy
- Use of very remote renewable energy?



Sun

Energy-proportional processing

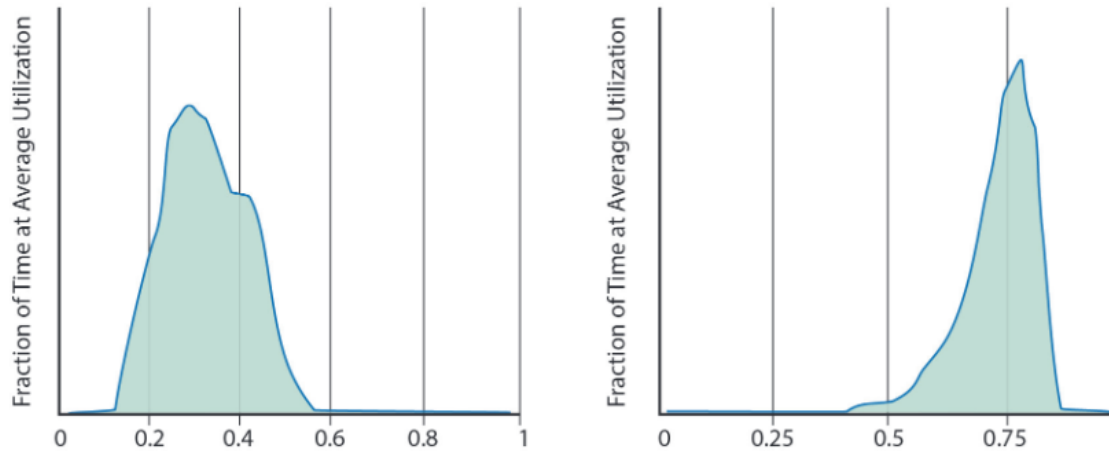
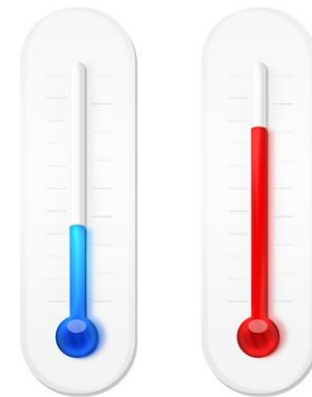


Figure 5.4: Average activity distribution of a sample of two Google clusters, each containing over 20,000 servers, over a period of 3 months (January-March 2013).

Energy-proportional storage (Facebook)

- Hot storage: read a lot
 - Replication/stripping across data centres
 - 3.5x stretch factor for resilience and performance
 - Data cools by 500x over 1st year
- Warm storage: read a bit
 - 2.5x stretch factor at lower performance
 - Migrate 1 month old data
- Cold storage: read almost never
 - Cheap drives by the million powered 1/15 of the time
 - 1.4x stretch
- Very cold storage: read never?
 - Optical (eg Blu-ray) thus little energy storage cost



Use of Renewable Energy

- Execute computing tasks where renewable energy is available
- Use renewable energy that cannot be used for another purpose
- Do we ship or replicate programs, data sets, or both?
- Will this change as photonic networks evolve?

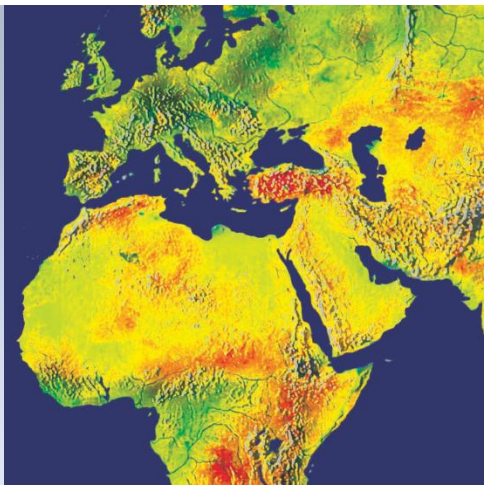


Siemens press picture

Technology Perspective

- Technology trends
 - Better hardware performance and power scalability
 - “Internet of Things”
- Workload trends
 - “Big Data”
 - Increasing large data and batch computations
- The future
 - Energy proportional computing, networking, and storage?
 - How much of the world’s computing will use surplus energy?
 - Ultimate processing architecture: latency or energy driven?
 - Ultimate storage architecture: store everything for ever?





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Physical to Digital

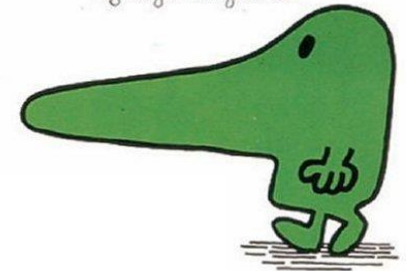
2 – Computing for Green

- A sensor-based digital model of everything
- “Googling” Earth in space and time
- How do we do it?
 - coverage
 - fidelity
 - scalability
 - performance
 - usefulness

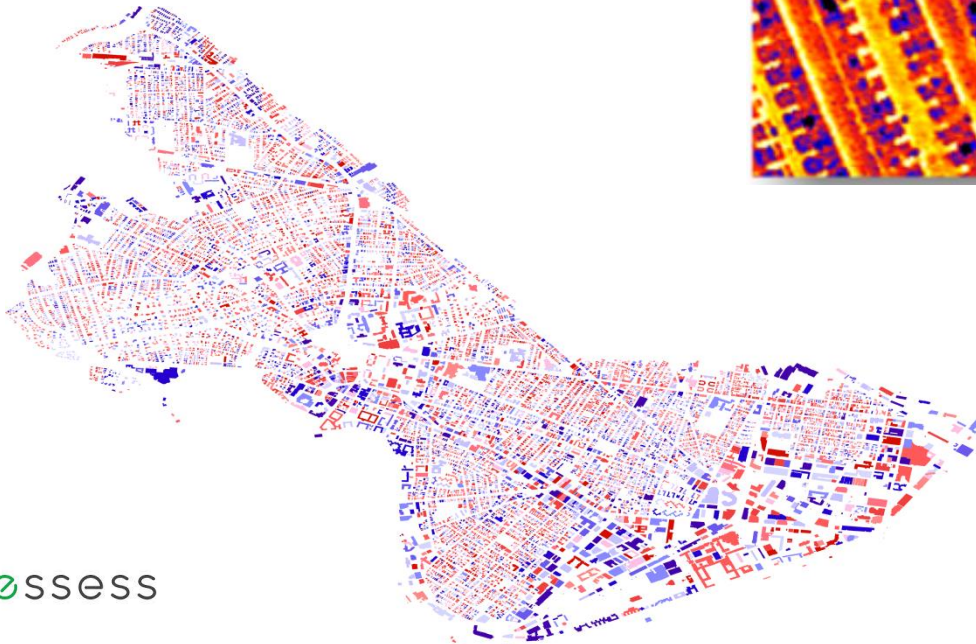
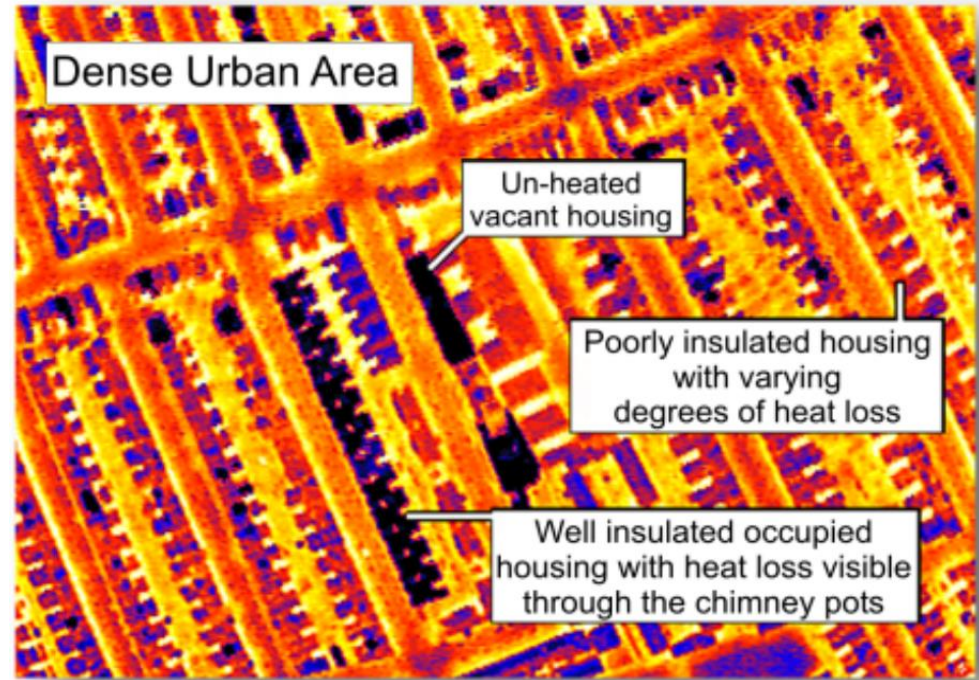


MR. NOSEY

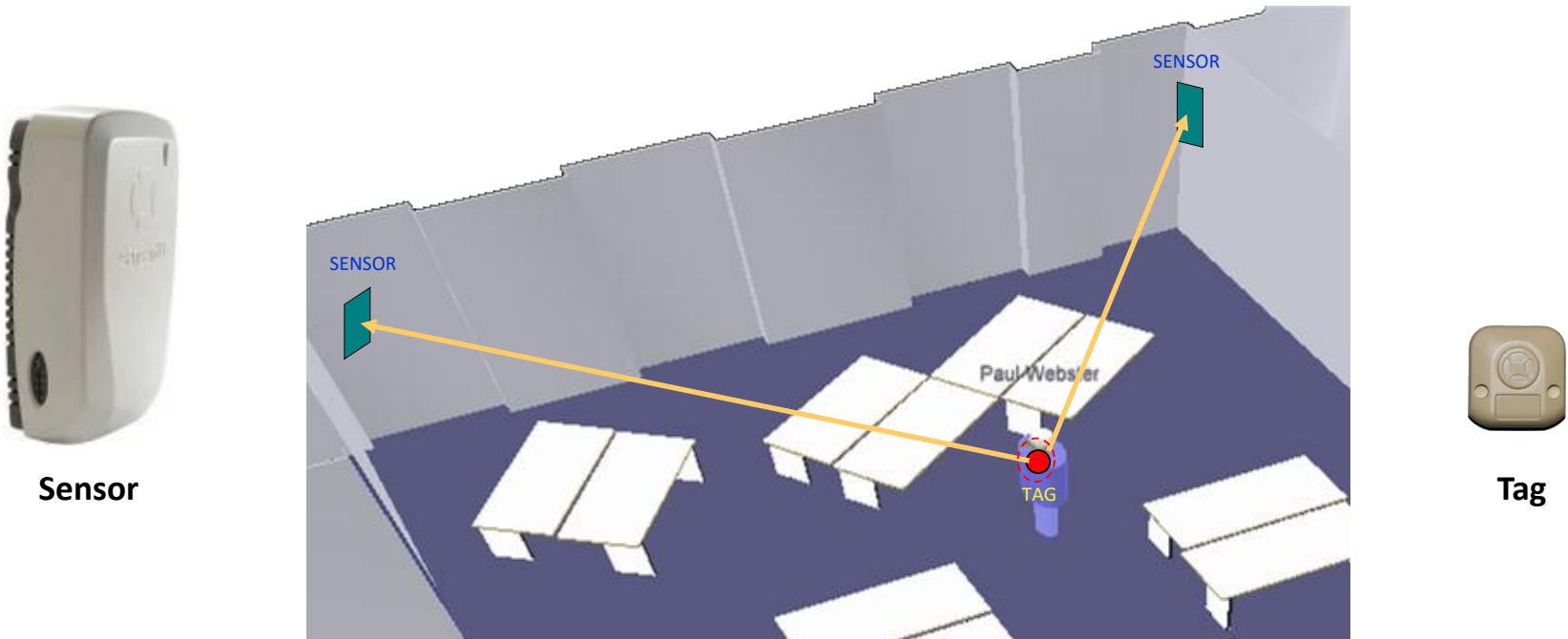
by Roger Hargreaves



Future Street View – Heat Sensing?

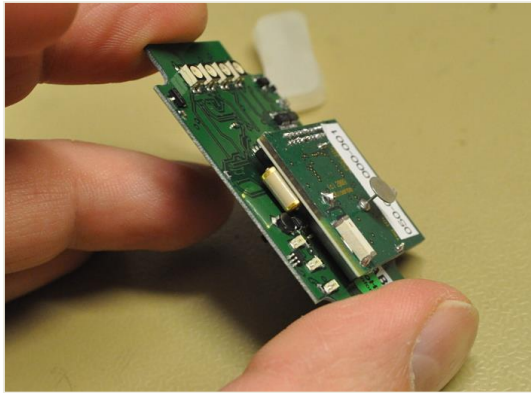


Indoor Location



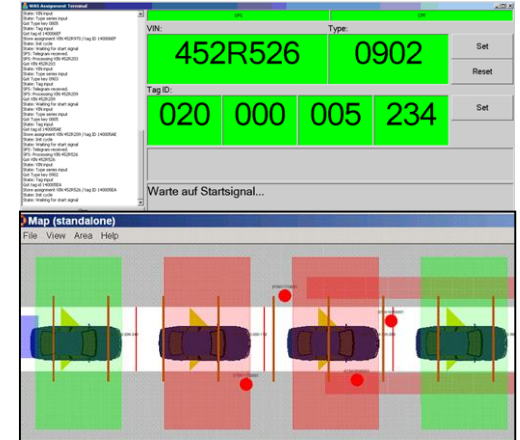
- ❖ Active tag and receiver infrastructure
- ❖ 3D accuracy up to 15cm (95% confidence level)
- ❖ Max range up to 160m

Tag integrated with tool



BMW Car Plant, Germany

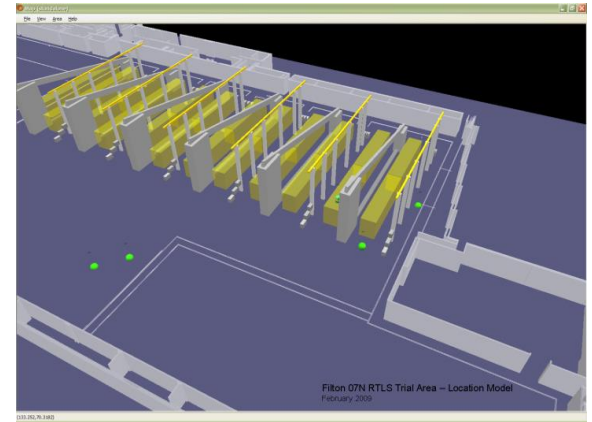
(Final Assembly Tool Assistance)



- Tracking tools on a complex production line
- Automatically programs tool with correct settings for each car
- Fewer manual processes, reducing errors

Multiple Airbus sites in Europe

(Process Tracking)



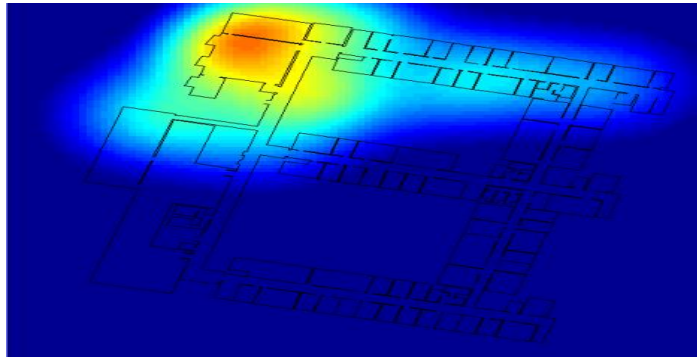
- ✪ Process monitoring across multiple factory sites in UK, France, Germany
- ✪ Provides central overview of process state
- ✪ Automatically updates planning system

Smartphone tracking

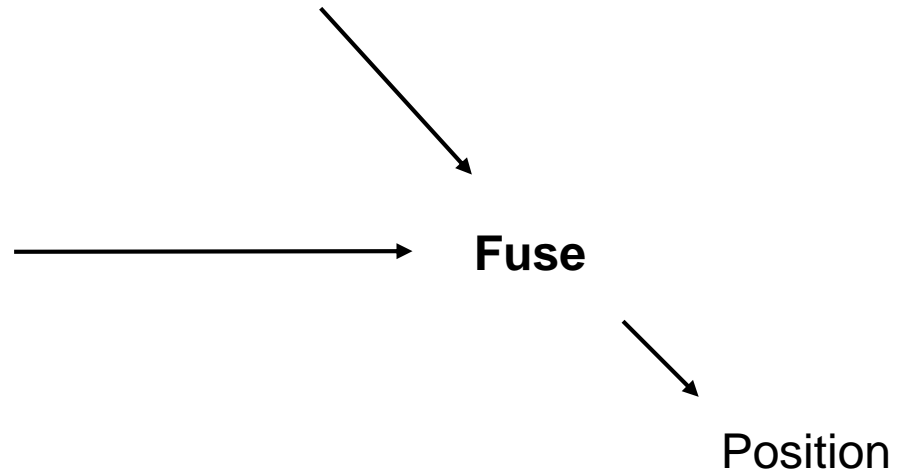
R. Harle et al



Accelerometers
Gyroscopes
Compass
Barometer
WiFi
Cellular
Bluetooth
NFC, RFID
Whitespace radio
Light
Temperature
etc



Knowledge of environment
Motion models



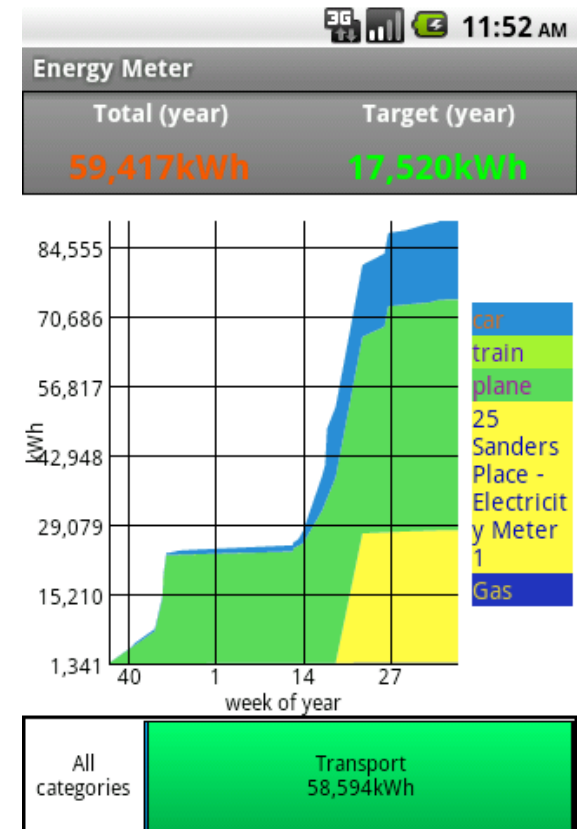
DeviceAnalyzer for Android



Global Personal Energy Meter - PEM

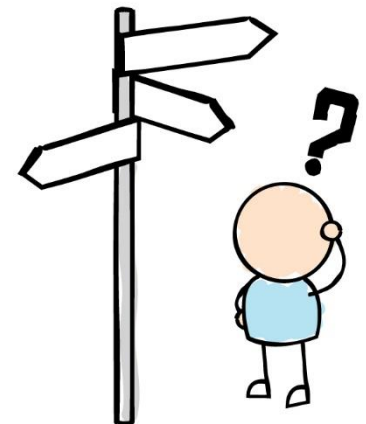
A. Rice et al

- Complete
 - all energy accounted for: sensed, embedded, shared, hypothecated
- Accurate / Bounded / Personalised
 - my actions relate to me only
- Sensible
 - incentives work correctly
- Assured
 - rules are understood
 - fidelity / error bounds
 - security / privacy



Privacy Dilemmas

- Privacy vs Sustainability
- Privacy vs Public Good
- Privacy vs Unexpected Consequences (eg Facebook)
- Privacy vs Wealth Creation
- Who is Big Brother anyway?



Framework for Big Data

- Collection
 - Transparency, Consent, Purpose, Access, Withdrawal, Accountability
- Governance
 - Who owns it
 - Who do we trust
 - How does business work
 - How does society work





Green Computing



Computing for Green

Guaranteed Computing



Wealth Creation

3 – Guaranteed Computing

- Increasing societal dependence on computing and automation
 - Complex systems
 - Advances in machine learning and artificial intelligence
- Technical challenges
 - correctness, bounding of errors
 - data archiving, code archiving, audit trails, transparency, repeatability, provenance
 - security, privacy



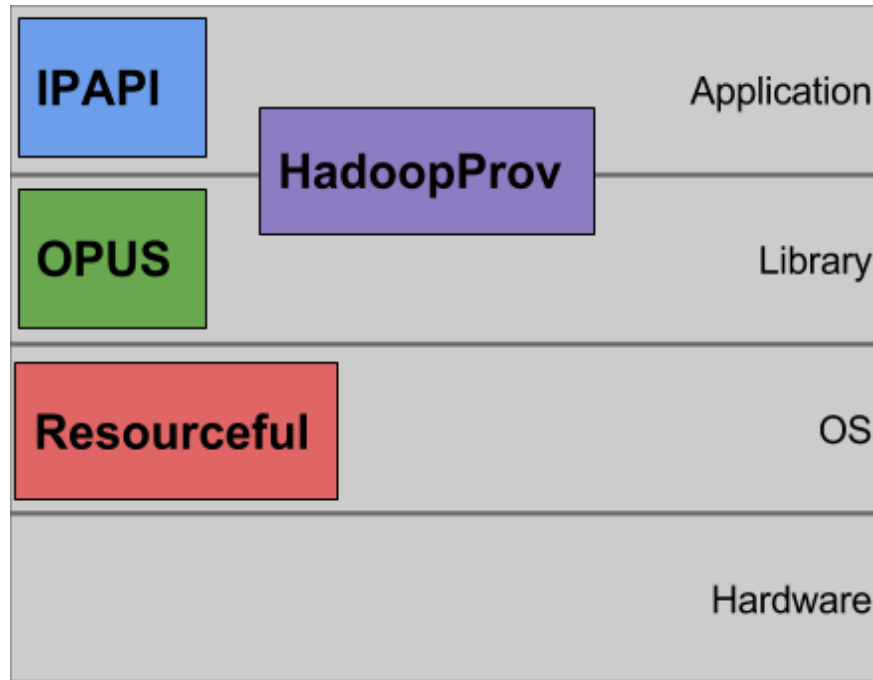
Provenance in Guaranteed Computing Systems

R. Sohan et al

- Complete history of a piece of data and its transformations
 - Can be applied at various levels
- A component of Guaranteed Computing Systems
 - Promulgate all changes to data
 - Invalidate backwards and compute forwards
 - Automatic or on-demand implementation
- Uses
 - Validation and Reproducibility
 - Audit and Compliance
 - System Optimisations
 - Reversible consent for exploratory use of Big Data?



Ongoing Projects



IPAPI – An Improved Provenance API

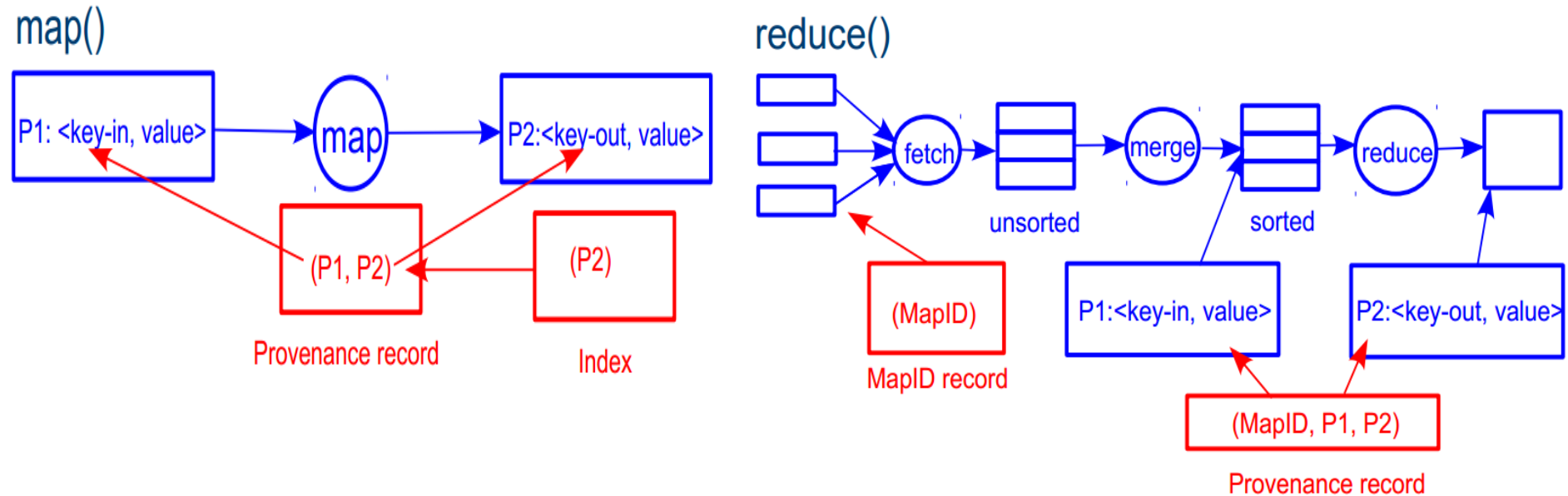
HadoopProv – A tool for augmenting “Big Data” programming

OPUS – Observational Provenance in User Space

Resourceful – System-call level Resource Accounting

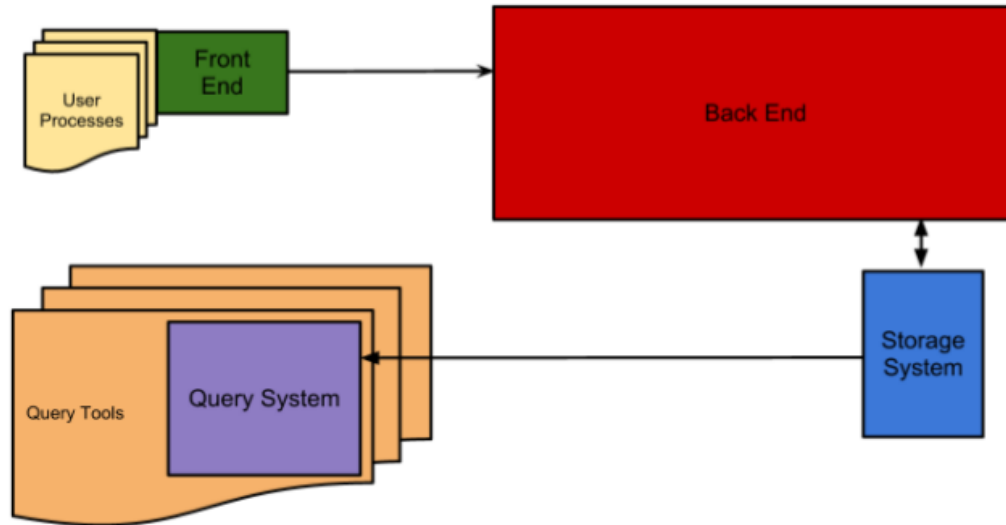
HadoopProv: Provenance For MapReduce

S. Akoush et al



- Capture key-value record dependency for across entire work-flow
- Low (<10%) temporal overhead
- Enables forward and backward key-value trace
- Uses: verification, validation, subset processing

OPUS: Observational Provenance In User-Space



- General purpose process-level provenance capture for POSIX
- Record all process I/O calls at library level
- Low use barrier, low overhead, always on

Relation Between Cat Colour and Popularity

Fluffy Cat
University of Cambridge
fluffy@cat.ac.uk

Abstract

Lorum ipsum dolor sit amet, consectetur adipiscing elit. Maecenas ante quam, tunc etiam moris idcirco, vulgare dictum ante Phaselia loboris nullus erat, id vehicula velit tunc hinc hinc. Nulla namque leo, aptus vitae ornatus, facilis dictum idcirco. Maecenas placeret moris leo, a finibus lorum variis erat. Cum sociis natoque penatibus et magnis disparturient moris, nascitur ridiculus mus. Suspendisse et nunc variis, finibus dolor vitae, tempus nunc. Aenean tempus, erat vel tempus interdum, lorum dui loboris nulla, dignus pretium augue tempus aptus idcirco. Moris interdum blandi idcirco. Phaseliaque porta tempus ac lectus elementum, ut sagittis et vestibulum.

1. Introduction

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Figure 1: Sample of a 'Cat Photo'

2. Methods

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Color	Whole Dataset	First Half	Second Half
White	3	1	2
Black	19	9	10
Grey	321	162	159
Brown	72	27	45
Orange	17	11	6
Green	55	33	22

Figure 2: Raw Values of Colour Occurrences

hendrerit. Quisque vitae arcu, ut congue erat. Fusce ornatus ante bibendum, vulputate erat ac, ultrices massa. Proin ut porta libero, non dignus massa. Moris volutatis erat in gravida mattis. Maecenas dui, interdum idcirco, in lectus nunc sagittis nec.

3. Results

Quisque ut aliquam lorum, ut viverra erat. Massa sed posuere moris. Sed ut sagittis ut. In elementum leo ac ornatus aliquam, quis faucibus elit moris. Proin non efficitur quam, a volutatis. Duis vehicula ornatus porta congue. Pellentesque ornatus, tempus et massa vehicula tempus nec tempus massa. Ut ornatus dui ornatus vel erat. Nullam id ornatus nec. Duis ornatus dignus dolor dui gravida.

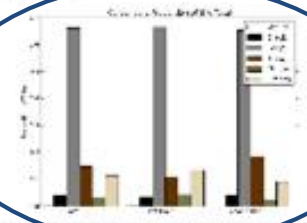


Figure 3: Annotated Statistical Representation of Colours

4. Conclusion

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How?
When?
Why?

Dataset



Green Computing



Computing for Green

Guaranteed Computing



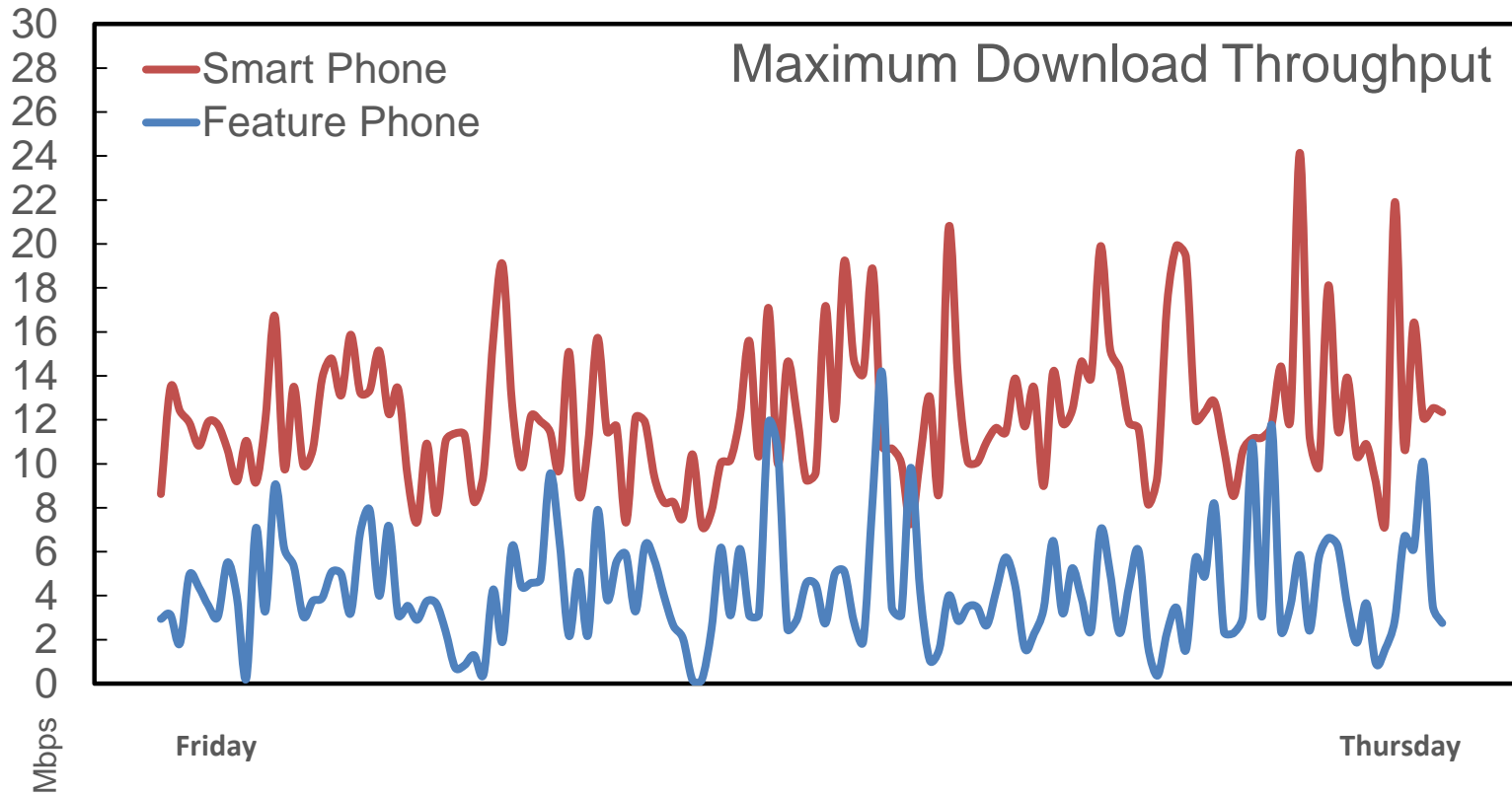
Wealth Creation

4 – Wealth in Cyberspace?

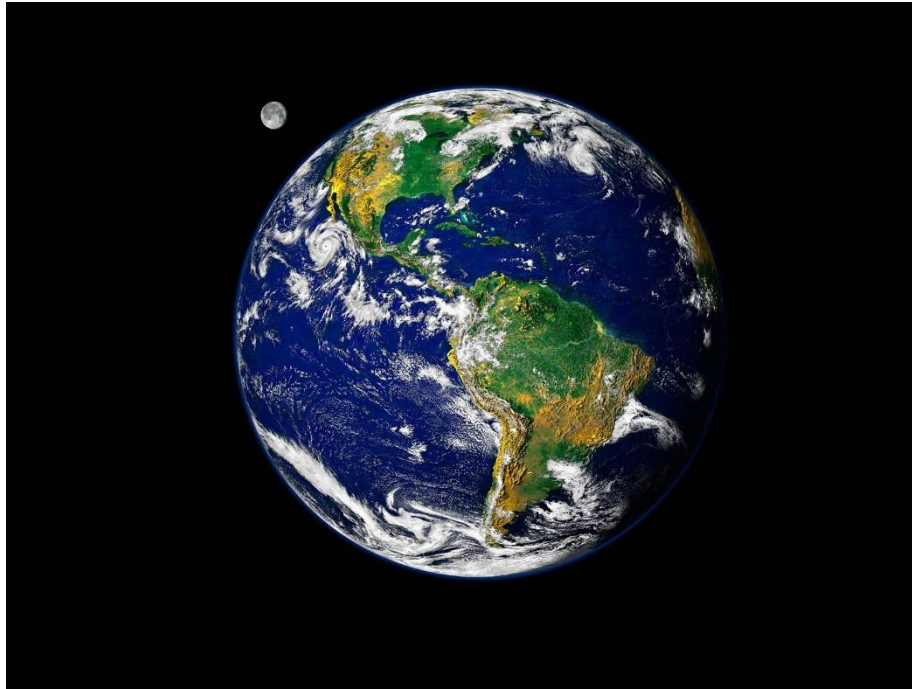


- Can we construct a digital world in which we can conduct our lives?
 - On a ultra-cheap platform
 - Using miniscule power
 - Fed with sensor data from the real-world
 - Accessible to everyone and everything
- Opportunity for the “Developing World” to bypass intermediate steps
 - Create wealth with a smaller footprint

Mobile traffic in Rwanda



Its happening!



- Coverage of cellular infrastructure is over 75%
- Auto-rickshaw: mGaadi, PoochO
- Amazon Mechanical Turk is a crowdsourcing marketplace for work
- MOOCs for education, eg: isaacphysics.org
- etc



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Infrastructure



Sense and Optimise



Predict React Automate

Physical to Digital