CLOUDs:
A large virtualisation of small things

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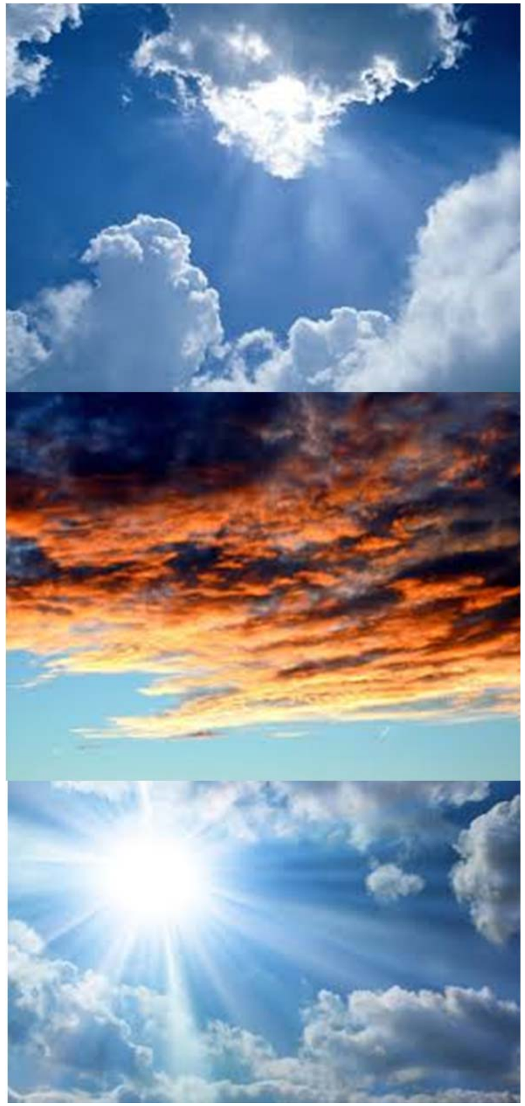
Structure

- Introduction – Who?
- Setting the Context
- CLOUDs
- IoT/FI
- R&D in CLOUDs
- PaaSage
- Conclusion



- 1960s Used computers for PhD (Geology) (relational system)
- 1970s led Geological Survey London Computing Team (G-EXEC Team)
- 1970s Led NERC Central Computing Group based at Atlas (G-EXEC Team)
- 1980s Led SERC database, office systems groups (e-library, CRIS, science)
- 1990s Led SERC Systems Engineering Division (R&D) (KE, SE, DE, W3C)
- 1998 Became CCLRC Director, IT (e-Science, CRIS, e-library)
- 2013 retired from Civil Service

Rutherford Appleton Laboratory

1960s to 2010s

Associations

W3C®

ERCIM
European Research Consortium for Informatics and Mathematics

APA
ALLIANCE FOR PERMANENT ACCESS

Very Large Data Bases

euroCRIS
Current Research Information Systems

ERF
European Association of National Research Facilities Open to International Access

EDBT

EOS

RDA
RESEARCH DATA ALLIANCE

=: SOFSEM :=

PAASAGE

EC CLOUDs Expert Group

Report 1: Work 2010,
Event January 2011

http://cordis.europa.eu/fp7/ict/ssai/docs/cloud-report-final.pdf

Report 2: Work 2011,
Event May 2012

http://cordis.europa.eu/fp7/ict/ssai/docs/future-cc-2may-finalreport-experts.pdf

Roadmap: Work 2012,
Event December 2012

http://cordis.europa.eu/fp7/ict/ssai/docs/cloud-expert-group/roadmap-dec2012-vfinal.pdf

PAASAGE

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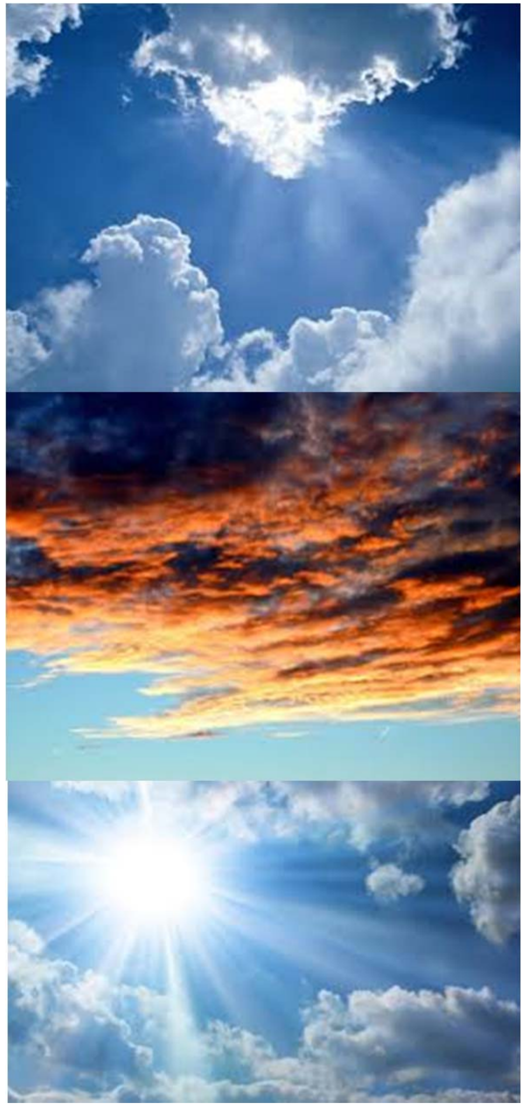
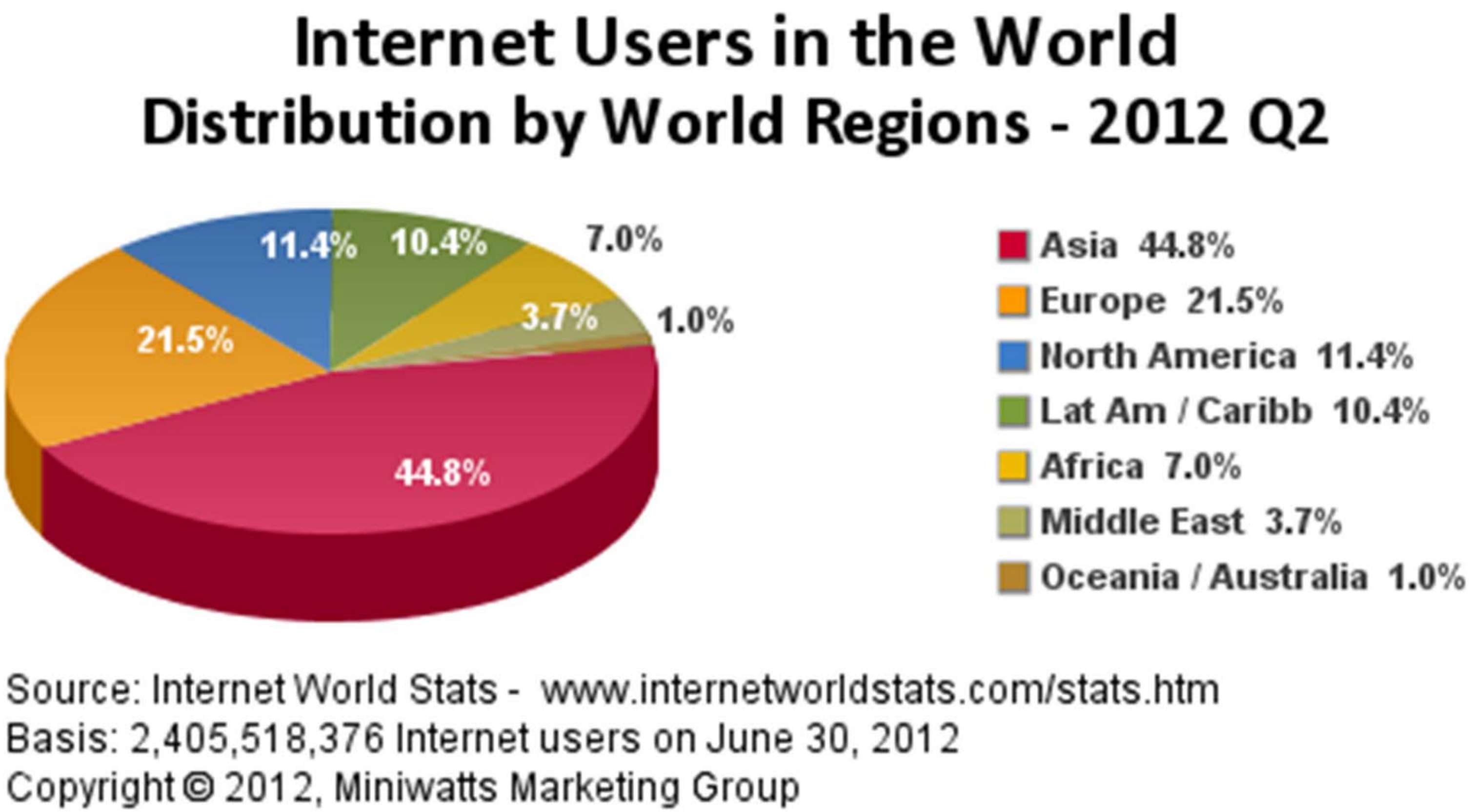
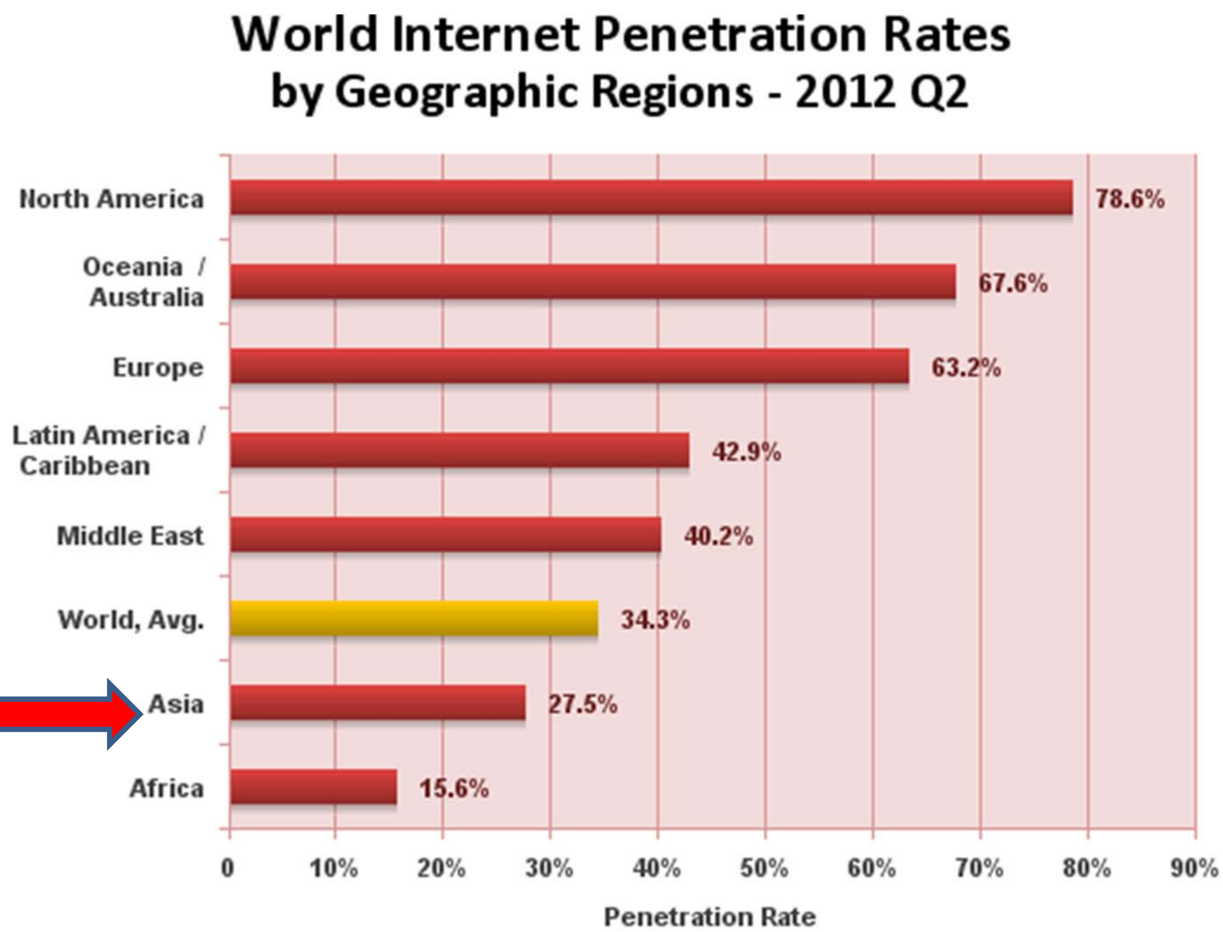


Internet Users by Region



The ASIA Timebomb

ASIA has largest population, largest number of users but relatively low penetration



Source: Internet World Stats - www.internetworldststs.com/stats.htm
Penetration Rates are based on a world population of 7,017,846,922
and 2,405,518,376 estimated Internet users on June 30, 2012.

Cisco Forecast Highlights: IP

2012-2017 : 3-fold increase

- Globally, IP traffic will grow 3-fold from 2012 to 201 … d annual growth rate of 23%.
- Globally, IP traffic will reach 120.6 Exabyt … 2017, up from 43.6 Exabytes per month in 201 …
- Global IP networks will carry 4 … ay in 2017, up from 1.4 Exabytes per day in 201 …
- Globally, IP traffic will … run rate of 1.4 Zettabytes in 2017, up from an … of 522.8 Exabytes in 2012.
- Global IP tr … be equivalent to 362 billion DVDs per year, 30 … month, or 41 million DVDs per hour.
- In … yte equivalent of all movies ever made will cross … works every 3 minutes.
- G … , IP traffic will reach 16 Gigabytes per capita in 2017, up fr … 6 Gigabytes per capita in 2012.

Cisco Forecast Highlights: Mobile

- Global Mobile traffic grew 70% in 2012.
- Globally, mobile data traffic will grow 13-fold from 2… …ompound annual growth rate of 66%.
- Globally, mobile data traffic will reach 11 … …onth in 2017, up from 885 Petabytes per month in 2012.
- Global Mobile was 2% of total IP … …nd will be 9% of total IP traffic in 2017.
- Global Mobile was 3% … …raffic in 2012, and will be 12% of total Internet traffic in …
- Global mobi… …grow 3 times faster than Global fixed IP traffic from 2012 to …
- Gl… …a traffic in 2017 will be equivalent to 5x the volume of the … …ernet in 2005.

2012-2017 : 9-fold increase

Mobile Internet

- **The number of mobile-connected devices exceeded the world's population in 2012.**
- There will be over 10 billion mobile-connected devices in 2016;

Issues

Elastic scalability

up/down/out/in; big data; energy; costs

Trust & security & privacy

Manageability

Accessability

reliability, availability

Useability

Representativity

These are issues for CLOUD Computing and IoT i.e. FI

Non-user devices

- The vast majority of computers – 98% - do not have traditional keyboard, mouse, screen
  - They are in cars, planes, washing machines, mobile phones
- The most-used operating system is NOT Windows (or Unix / Linux)
  - Symbian in mobile phones ➔ Android & iOS
  - or specialised operating systems (e.g. Contiki) in embedded systems

Social Context

- The number of computers will vastly out-number humans on the planet very soon;
- Everything will be computerised (IoT);
  - Sensor networks
    - Home, healthcare, environment, industrial processes, transport systems….
  - Control systems
    - Industrial, transport, home (central heating)…
- **How do we control the social acceptance**
  - **Inappropriate material – pornography**
  - **Inappropriate behaviour – trolling**
  - **Unwanted advertising**
  - **Invasive business practices**
- **How do we assure security**
  - **Continuity of services despite internet terrorism**
  - **Or even accidental disruption**

Especially via personal devices: smartphones, Google glasses

So…

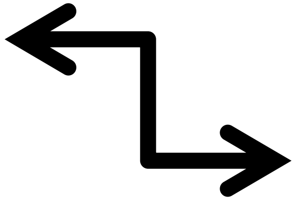
- This is the ‘internet of things’ or ‘future internet’
- We need to :
  - Manage the huge numbers, sizes
  - Integrate the different kinds of systems
  - Into one environment leading to human decision-making
    - whether managing a business, shopping, media choice, social interaction
- But there is a problem…in last 20 years
  - Data storage density increased ~10**18
  - Processor power increased ~10**15
  - BUT broadband capacity increased ~10**4

- This has implications for Information Systems Engineering!
- In fact the requirement and limitations challenge the very basis of traditional computer science / ICT

Era 1


User request, programmer, punched cards, low-level program, mainframe

Era2



User interacts with in-house-written software in high level language on mainframe or mini. Network proprietary.

Era3

User interacts with off-the-shelf software on PC which interacts with in-house-written or purchased software on mainframe. Client-server to 3-tier. Network is (becoming) internet

Era4

User interacts with pre-written software on mobile device which interacts with pre-written software on mainframe. Network is internet WiFi, 3G, 4G… and using WWW

CLUSTERs & GRIDs

Having virtualised the way the user interconnects to the application on the mainframe (Client-Server or 3-tier)

the next logical step is to virtualise the mainframe

CLUSTER
- Racked mainframe in-house
- Homogeneity
- Dynamically reassigned resources

GRID
- Distributed racked mainframes
- Heterogeneity
- Dynamically reassigned resources
- Mobile Code

Which leads us towards CLOUD Computing

Software

- Just to mention there has been an evolution in:
- Programming languages
  - Machine code, autocode, 3G, (imperative), 4G (declarative); functional
- Data modelling and management
  - Lists, hierarchies, networks (E-R), graphs (EER, ORM)
- Software and systems design
  - Including human factors, adopting new modalities (mouse, gesture, speech)
- Systems development methods
  - HIPO, Jackson, SSADM, PRINCE (waterfall to spiral)
  - Object-orientation (aspect orientation)

Overall Trend

- Virtualisation
  - User neither knows not cares how the requirement is met as long as it meets SLA/QoS
- Pervasiveness
  - Computing everywhere, all the time via personal devices;
  - Continuous monitoring and information provision
- PROBLEMS
  - Capacity and performance
    - Especially bandwidth
  - Trust, security, privacy
  - Making heterogeneity appear homogeneous

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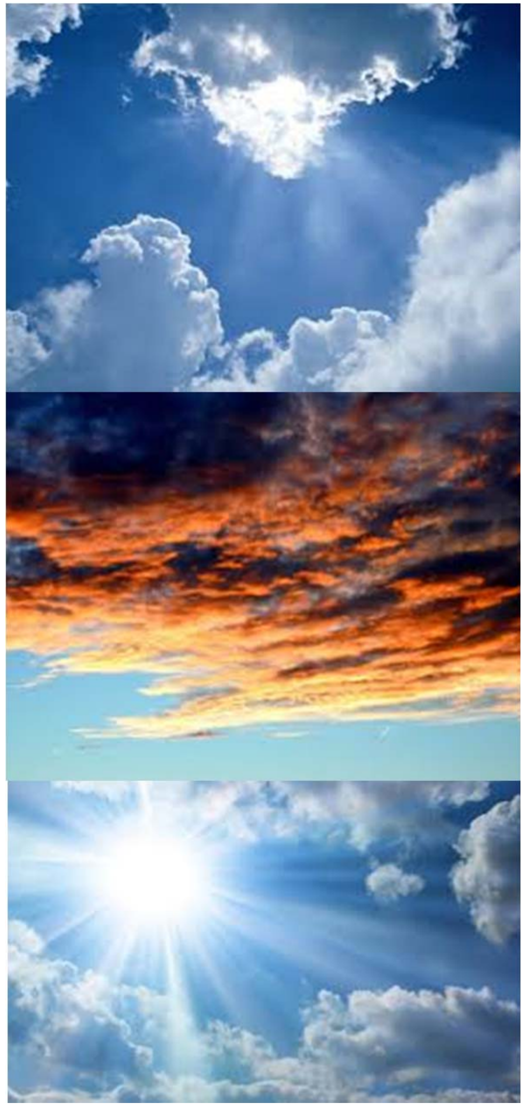
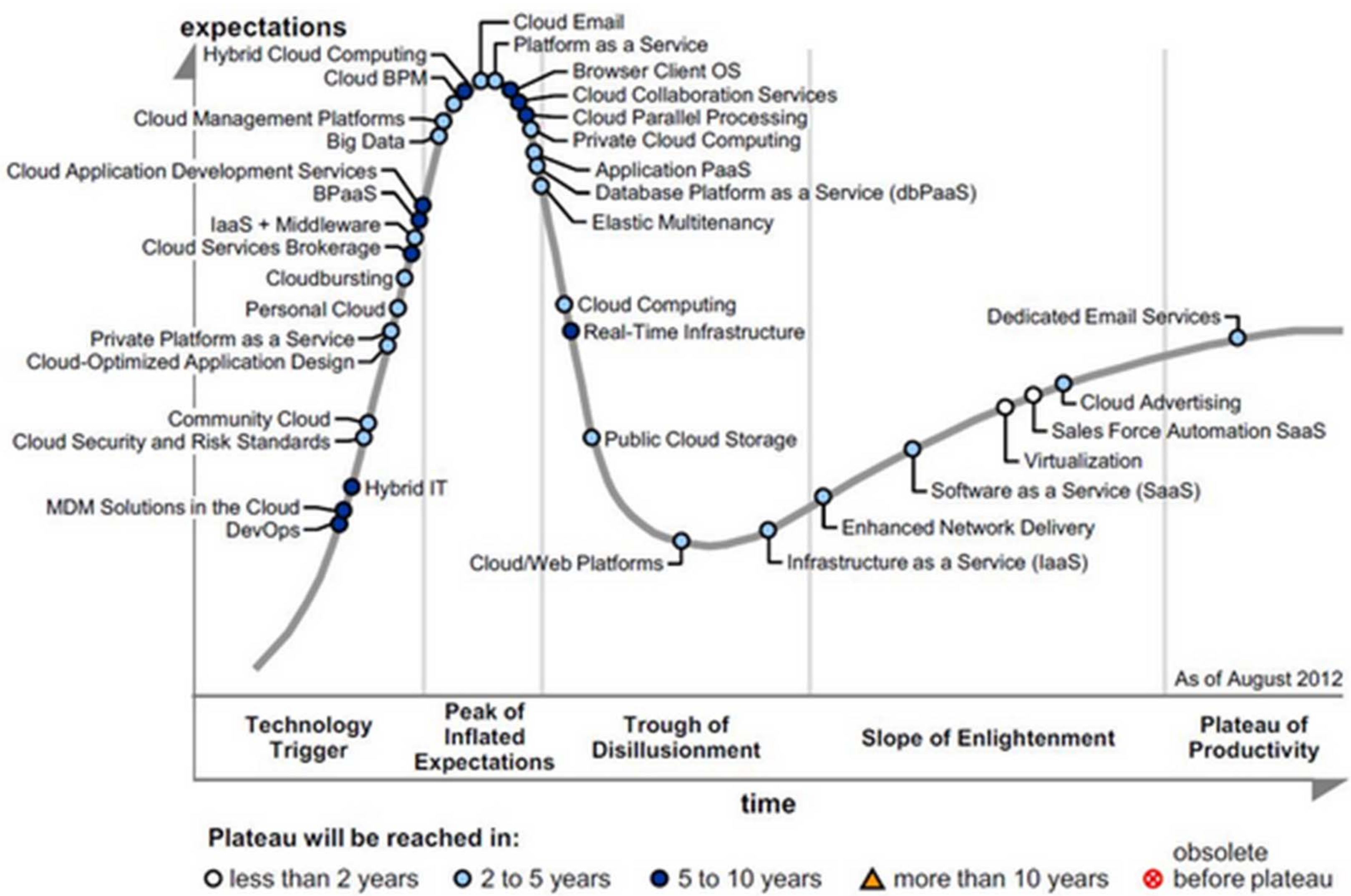


Gartner Hypecycle

Figure 1. Hype Cycle for Cloud Computing, 2012



Source: Gartner (August 2012)

Gartner Hypecycle

- Few production business applications CLOUD-established
  - although used for office functions and data sharing
  - and experimentation
- In next 2-5 years some technologies will come through- IaaS, SaaS, Application PaaS, Private Clouds
- But Cloud services brokerage and cloud services development environments are 5-10 years away

Cloud Computing

Hardware

- A very large number of processors
  - Clustered in racks as blades
- In one major computer centre
  - May be replicated for business continuity
- With massive online storage
  - RAID for resilience
- And excellent communications links
  - For access

Economies of scale – both purchasing and operation

Energy economies in location

Staffing economies in location

Cloud Computing

Customer View

- Low cost of entry for customers
- Device and location independence
- Capacity at reasonable cost (performance, space)
- Cloud Operator manages resource sharing balancing different peak loads
- Elastically scalable as demand rises (or falls) from user
- Security due to data centralisation and software centralisation
- Sustainable and environmentally friendly – concentrated power

- → it is a service and the user does not know or care from where, by whom, and how it is provided
- → as long as the SLA (service level agreement) QoS (quality of service) is satisfied
- → it is a 'computing utility' (IaaS, PaaS, SaaS….'XaaS')

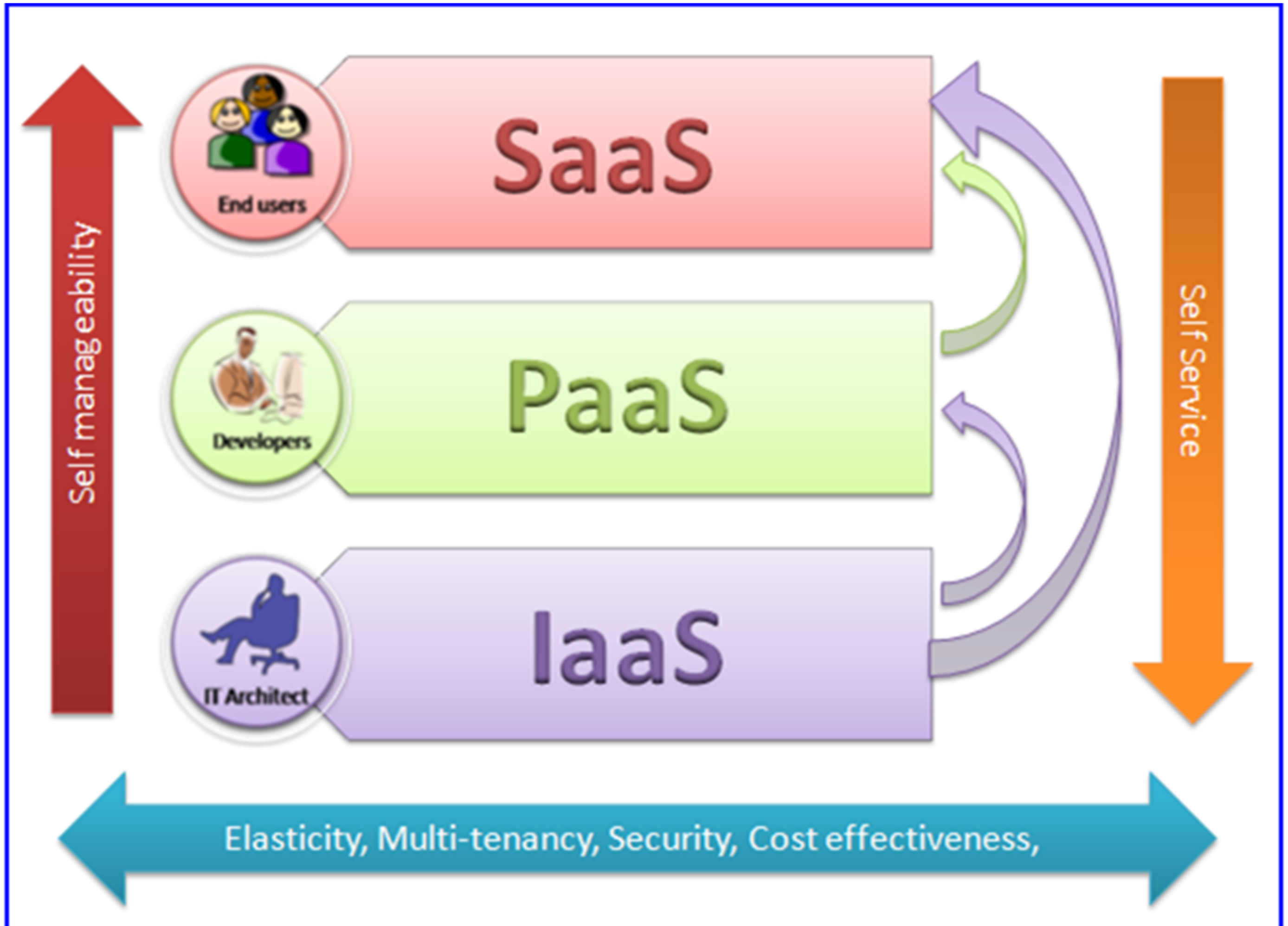
Cloud Computing

Ownership

- Private Cloud: in-house cluster run using CLOUD middleware;
- Public Cloud: outsourced computing to commercial provider – proprietary;
- Hybrid Cloud: linked Private and Public CLOUDs

Cloud Computing

Offerings



Acknowledgements
to U Southampton

How does it work

- Multitenancy: Cloud resources (hardware) shared dynamically between customers;
- Each customer application in its own virtual machine
  - Isolation for security, privacy
  - Allows scheduling with respect to shared resources

Cloud Computing

What is it?

- Is cluster computing
  - with the advantages that brings
  - But distributed
- With GRIDs features
  - Scheduling / resource allocation
  - self-*
- ASP (Application Service Provider)

Cloud Computing

- Obtains from GRIDs work:
  - resource sharing/scheduling
  - virtualisation of hardware and low-level software (under middleware)
  - resilience
  - trust, security, privacy
  - (more or less) self-*
- Utility computing
- Autonomic computing

Cloud Computing

- Obtains from software/systems engineering:

- Service-Oriented Architecture
- with implications of interfaces, metadata, composition

But the real novelty is…

- Pay-As-You-Go (only for what you need);
- Accounting for ICT used by departments in an organisation;
  - Private cloud
  - Public cloud
- CAPEX to OPEX

Cloud Computing

- Private Cloud Software : Eucalyptus
- Private/Hybrid Cloud software: Open Nebula
- Commercial examples of Public Clouds:
- Amazon EC2 Elastic Compute Cloud
- Google (Engine for Apps; Connect for Office)
- Microsoft Azure
- IBM SmartCLOUD
- (note all needed massive resource for infrequent use so could sell off excess capacity)

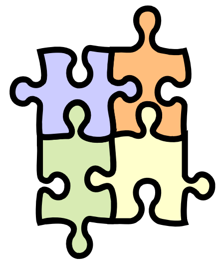
- Note Thomas J Watson in late fifties:
- "total number of computers required in the world is five"
- are we reaching this goal?

Cloud Problems

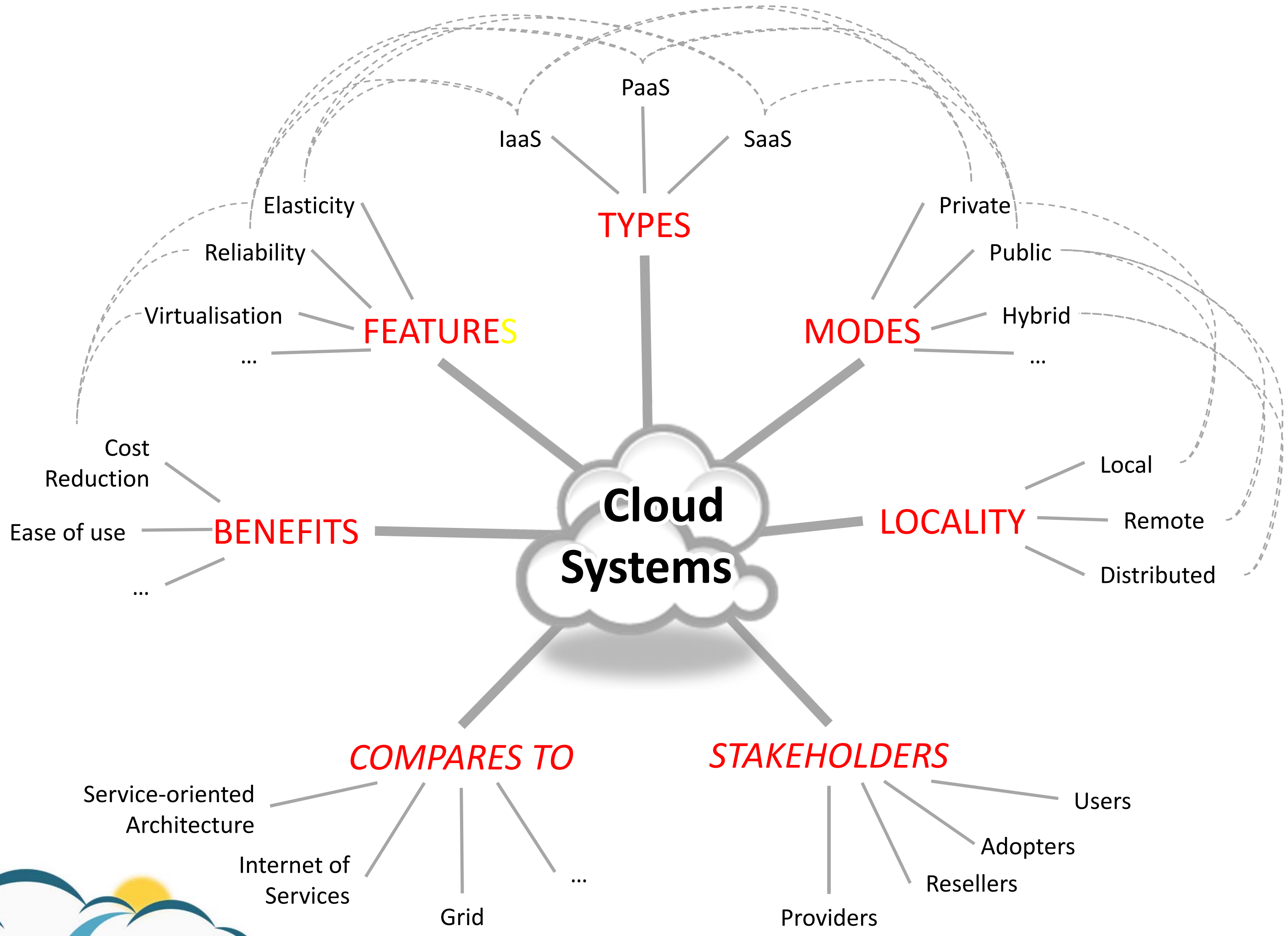
- Inefficient to move data to the cloud
  - Remember earlier comments about networking bandwidth

- Despite SLA/QoS guarantees some concerns:
  - Performance
  - Security/trust/privacy
    - Especially transnational

- Making heterogeneity appear homogeneous



Characterisation



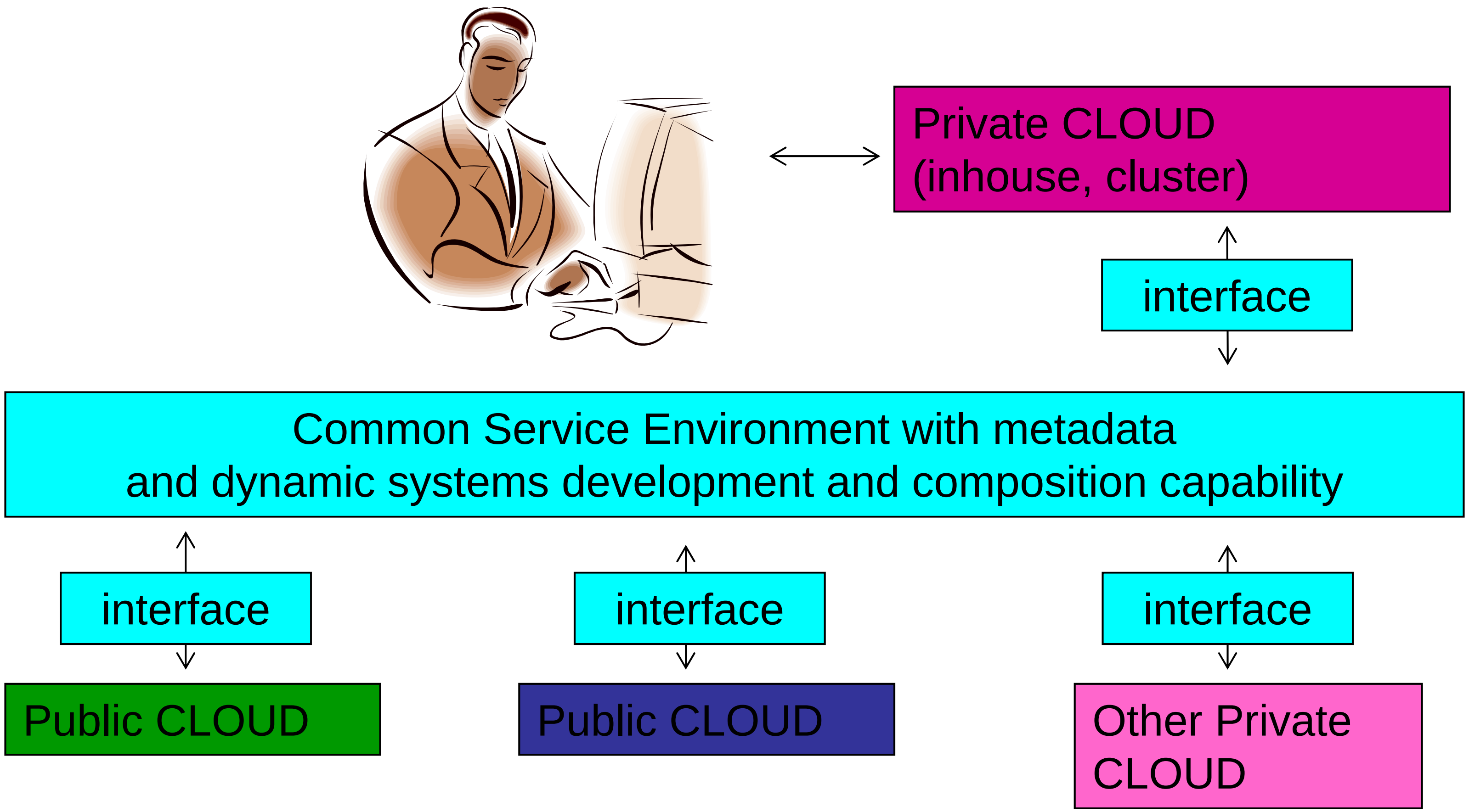
Characteristics

Non-Functional	Economic	Technological
relate to qualities of cloud systems, rather than technological aspects. These include: • Elasticity • Reliability • Quality of service • Agility and adaptability • Availability	key driver behind (commercial) cloud systems. Typical interest rests on: • Cost reduction • Pay per use • Improved time to market • Return of investment • CAPEX to OPEX • "Going green"	Arise from realising non-functional / economic concerns. Particular issues: • Virtualisation • Multi-tenancy • Security, privacy and compliance • Data management • APIs and / or programming enhancements • Metering • Tools in general

Legislation, Governance, Policies

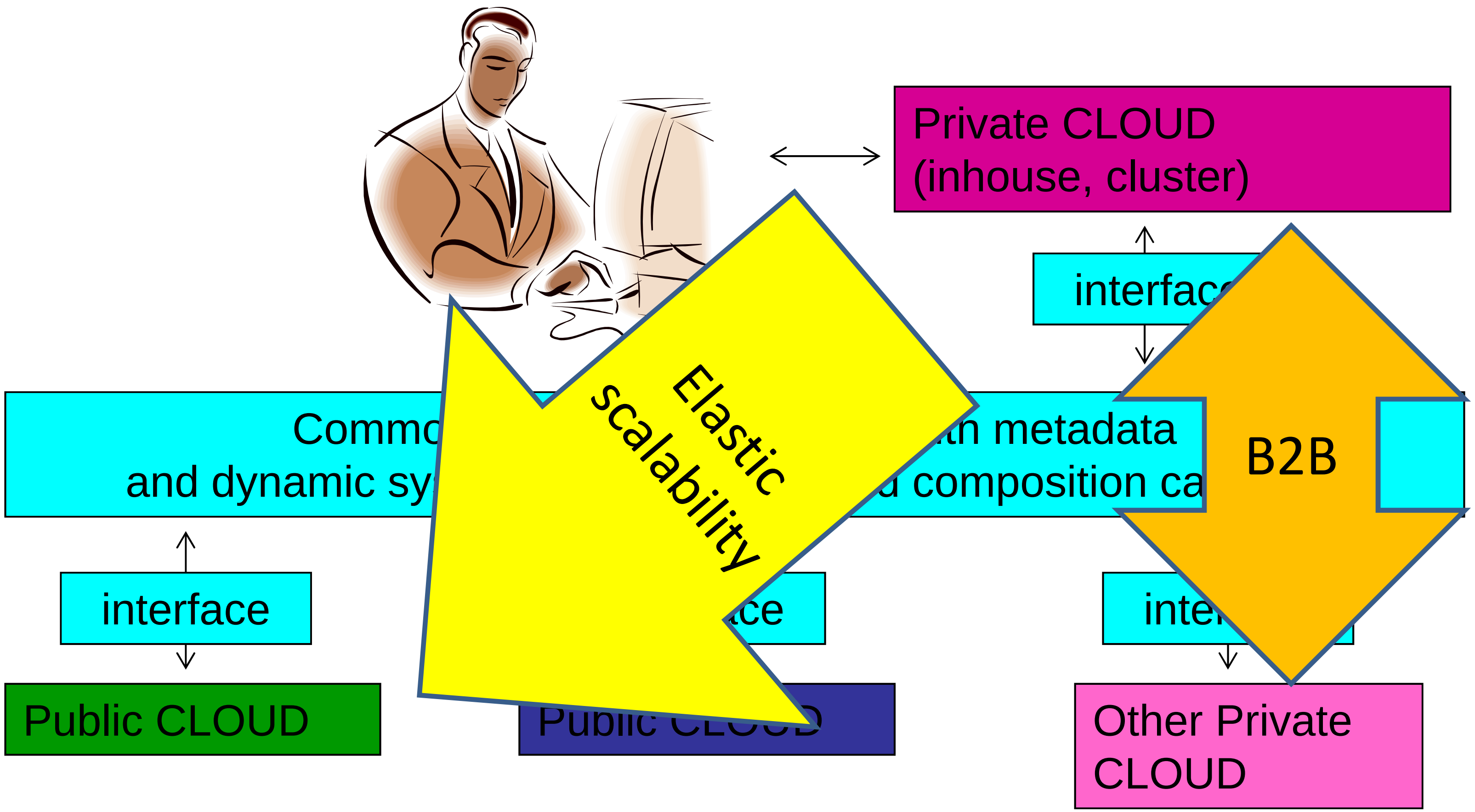
- No standards – vendor lock in
- Legality of operating / using CLOUDs
  - International jurisdiction
  - Privacy and personal data
- Security of operating / using CLOUDs
  - International jurisdiction
  - Security and investigatory powers
- No free market in services across CLOUDs

Target



Private CLOUD
(inhouse, cluster)
interface
Common Service Environment with metadata
and dynamic systems development and composition capability
interface
interface
interface
Public CLOUD
Public CLOUD
Other Private
CLOUD

Target



Private CLOUD
(inhouse, cluster)
interfac
Commo
and dynamic sy
th metadata
d composition ca
interface
ce
inte
Public CLOUD
Public CLOUD
Other Private
CLOUD
Elastic
scalability
B2B

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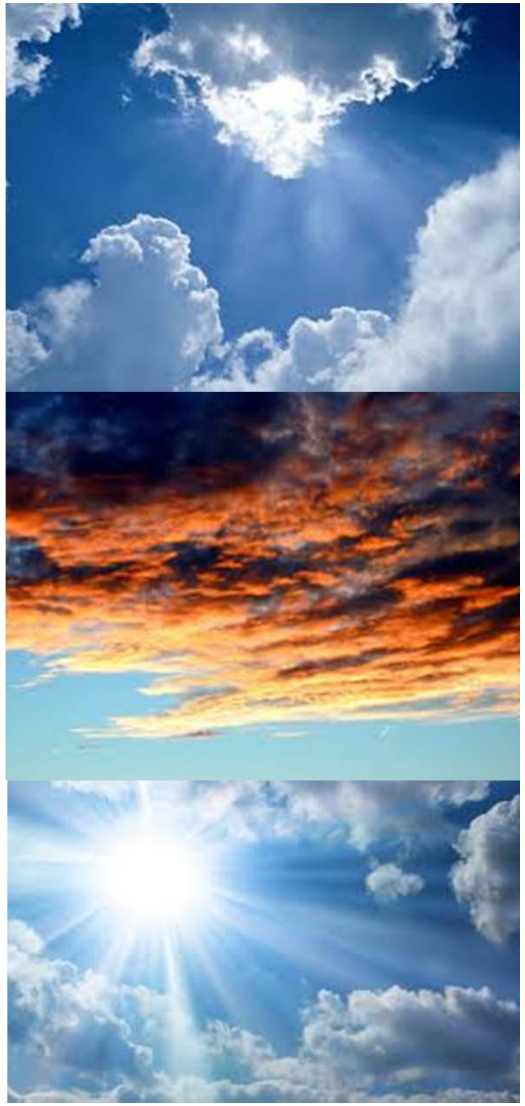


PAASAGE

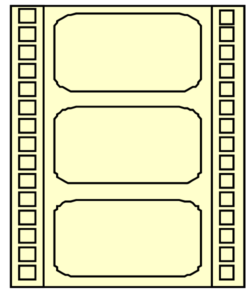
IoT/FI

- Internet of things:
  - many connected 'appliances'
  - With all the challenges that implies

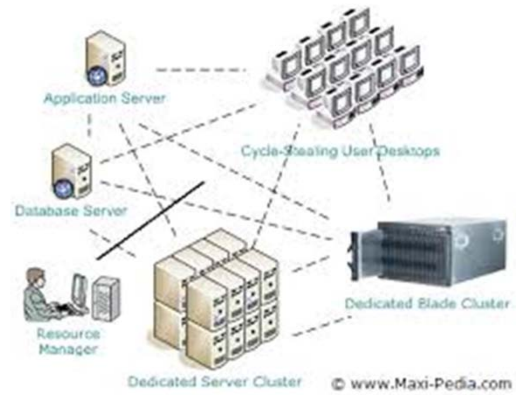
- Future internet:
  - IoT plus applications (Internet of Services)
  - With all the challenges that implies

IoT Issues 1

- Sheer number of devices
  - Managing them (sysadmin)
- Volumes / velocity of (streamed) data
  - Storage
  - Stream processing / windowing
- Specific formats and protocols
  - Conflicts with interoperability
- Intermittent disconnect



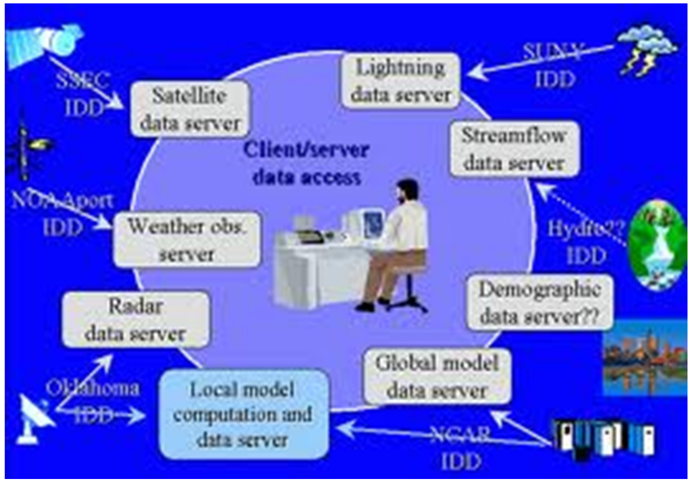
IoT Issues 2



- Distribution of processing
  - Averaging values at or near device
  - Aggregation for onward transmission
  - Multi-sensors multiplex into one stream
  - having sufficient compute power at sensor or sensor cluster
  - Dynamically re-assigning computing power

IoT Issues 3

- Distribution of data
  - Where to process?
    - Far (sensor) or near (datacentre)
    - Depends on bandwidth/ latency
  - Maintaining state
    - Consistent 'picture' of domain of interest
- Trust / security / privacy
- Power usage



FI Issues

- Same as IoT issues
- But particularised to services
  - Problems of standards
  - Problems of composition
    - Dynamic (re-)composition
- And to use of mobile user devices
  - Smartphones
  - Tablets
  - Wearables

Convergence

- So IoT, FI and CLOUDs share the same issues:
  - At different scales, volumes
  - In different configurations
- So R&D in CLOUDs has applicability also to FI

- Virtualisation
  - Usability
  - Interoperability
  - Elasticity
  - Accessability
- Management
  - Autonomicity
  - Energy
- Trust / Security / Privacy
- Data
  - Volumes, velocity
- SysDev methods
  - Programmablity
- Representativity
  - Information matches real world

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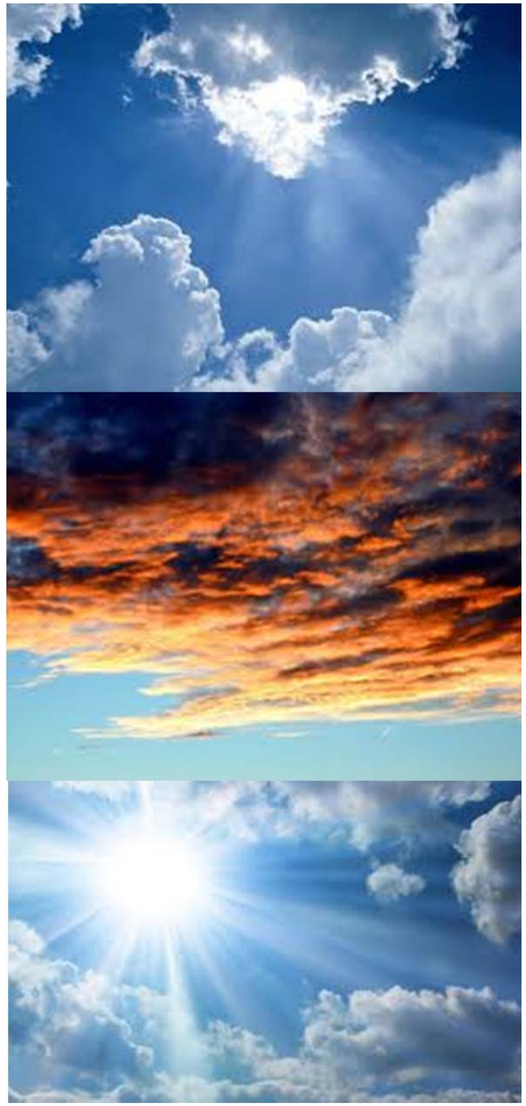

Current State of the Art

- Horizontal scale-out elasticity
- Reliable basic data storage
- Resource level QoS
- High availability
- Basic system level virtualization
- Basic security mechanisms
- Basic tenant separation (VMs)

GAPS

- Manageability and Self-* (autonomicity)
- Data Management
- Privacy & Manageable Security
- Federation & Interoperability
- Elasticity (Vertical and Down)
- Programming Models & Resource Control

Manageability and Self-*

- Efficiency & Overhead of management
- Interoperability of management frameworks
- Compensation for insufficient resources
- Boundary criteria (QoS, legal, environmental)

Data Management

- Data size (with new access patterns)
- Lifecycle control (compliance & economic)
- Multi-tenancy
- Flexibility, expressiveness
- Consistency and concurrency models*
- Partitioning and replication
    - Performance
    - Security

*see also programming models

Privacy & Manageable Security

- Multi-tenancy
- Provenance & compliance
- Composable security
  - Consistent across services
  - User role (temporal validity)
    - Authorities / responsibilities
    - Permissions (licensing…)

Federation & Interoperability

- Propietary de-facto standards
- Vendor lock-in
- Lack of agreed upon abstractions and interfaces for federation
  - QoS
  - Trust, Security, Privacy
  - (dynamic, partial (component)) Migration

Elasticity

- Rapid release of unused resources
- Scheduling with variable resources
  - Resource characteristics / appropriateness
- Vertical elasticity*
- Rapidly changing workloads

*see also programming models

Programming Models & Resource Control

- Vertical scalability
- Intelligent distribution of code & data
- Reliability
- Ease of Use
- Development and operations support

Making a RoadMap

- The expert group was asked after two reports to produce a roadmap indicating:
  - Importance of the technology
  - Urgency of its adoption for benefit
  - Expected returns on investment
  - Barriers to adoption
- Of each topic for Europe
- This led to 3 groups based on:
  - Features or characteristics required
  - Research objectives to meet those features

European Starting Position

Differentiators from international competition:

- Mobile Clouds
  - Growing field with high potential
  - Open market opportunity
- eScience
  - Basis for many advances in engineering, health, environment etc.
  - Data ownership / utilisation and existing infrastructures
- Governmental & Social Services over the cloud
  - Government supported, backed by research
  - eHealth services
  - e-Learning services (lifelong)
- Engineering
  - From e-Science – simulation, design, testing, production
  - Factories of the future – integrated robotics
- Energy
  - Smart GRIDs
  - Renewables – intelligent management

European SMEs can benefit quickly

Short Term Innovation

Quick Wins and Positioning for the Future

- Mobile support including support for BYOD
- Reduction of vendor lock-in
- Efficient handling of data and communication
- Better awareness of cloud capabilities and improved programmability of cloud services
- Useable management of trust, privacy and confidentiality
- Adequate market regulatory frameworks and viable business models
- Ensuring an affordable, international (at least pan-European) mobile data service

Mid Term Innovation

Consolidating, Significant business benefit, Aligned for Future

- Personal clouds
  - Europe is strong in embedded computing & telecommunication
- Sensor clouds
  - Key players in smart grids in Europe
  - Many scientists for emergency situation prediction
- Brokering
  - Particular chance for SMEs to profit from large providers
- eEngineering
  - Tools for smaller engineering & manufacturing companies
  - Strong European players (e.g. automotive)
- Media Clouds
  - Strong multimedia industry in Europe
- Collaborative environments
  - European services are B2B centric
  - Rich set of expertise in collaboration
- BYOD
  - Major opportunity for European operators – links to mobile CLOUDs
- Enriched services through composition
  - Particular chance for SMEs to combine & resell services
  - Strong European potential in selling enriched services

Long Term Innovation

Develop CLOUDs into a trusted commodity:

- Federated / merged clouds
  - Addresses concerns about lock-in and capacity
  - Specific potential in Europe due to the heterogeneous infrastructures
  - Requires programmability, interoperability
- Easy / automated composition
  - Similar potential to brokering & composition
  - Requires in-depth knowledge & support of applications
- Quality demanding services created on the fly
  - European eScience will act as a driver
  - Requires performance, big data
- Carry your environment
  - Next step of BYOD, increased mobility & efficiency
  - Requires smart networks

Main Research Topics

1. Data Management
2. Communication & Network
3. Resource description & usage
4. Resource management (Provider Support)
5. Multiple Tenants
6. Federation (& interoperability, portability)
7. Programmability & Usability
8. Political & Legislatory
9. Security
10. Business & Cost Models

Immediately Relevant Topics (short-term innovation)

- Managing data deluge
- Improved networking
- Improve the capabilities to exploit CLOUD features
- Improve the performance and portability of applications
- (Security) vulnerabilities
- Reducing vendor lock-in
- Comparability between offerings
- Viable business models / clear European benefit

Sustainability R&D Topics (medium-term innovation)

- better understanding of the relationship between application and user / usage behaviour
- Means to use that relationship – this includes
  - manage service discovery, (re-)composition and execution autonomically
  - allow developers to produce quickly and cheaply well-designed software
  - identification and provisioning of typical CLOUD usage patterns (cf. HADOOP)
- Deal better with the growing heterogeneity
- Paving the way for personalised service provisioning and usage
- Extended outsourcing and composition of capabilities
- Scalable orchestration of services and virtualised resources
- Maintain / improve trust through
  - Enhanced protection
  - Address privacy concerns

Paradigm Shifters

New paradigms to address the underlying challenges and 'leapfrog' the competition – longer-term innovation

- Dynamic (re-)composition of services; intelligent networking; cross-platform service deployment
- Big data managing integrity (state) and heterogeneity of data models.
- Declarative programming with execute-time data binding – for flexibility, heterogeneity, consistency etc.
- Interoperation and federation (heterogeneity and mobility) - appear to the application environment as one uniform platform.
- Exploitation of new device types and environments
  - advances in hardware for processors, storage, detectors and instruments and networks – along with associated low-level (embedded) software

What Stops us..

- I have listed a whole lot of CLOUD specific problems already such as:
  - Interoperability / vendor lock-in
  - Security, privacy
  - Quality of service / service level agreements
  - Legislation
- **But CLOUDs throws into sharp relief many underlying computer science / informatics problems**

Perennial challenges

- Metadata — to permit automated virtualisation
- State — to ensure information currency
- Data Representativity — to ensure accuracy
- Data quality, veracity, permanency — to assure
- Trust, security, privacy — to protect
- Management of service and quality — to comply
- Systems development methods — to productise
  - New programming paradigms
    - Co-design software with management
    - Built in trust / security / privacy
    - Dynamically (re-)composable services
  - Supporting toolsets

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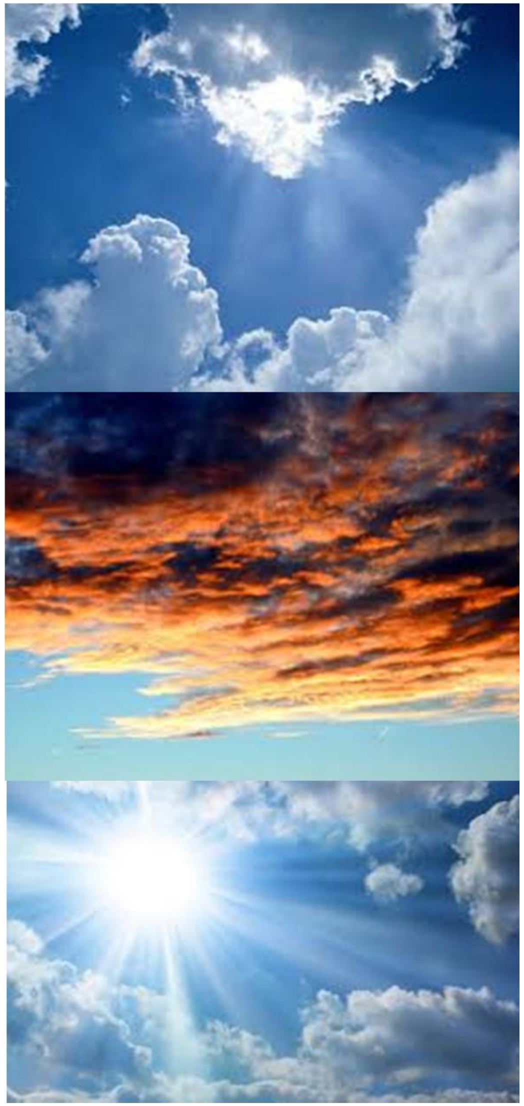
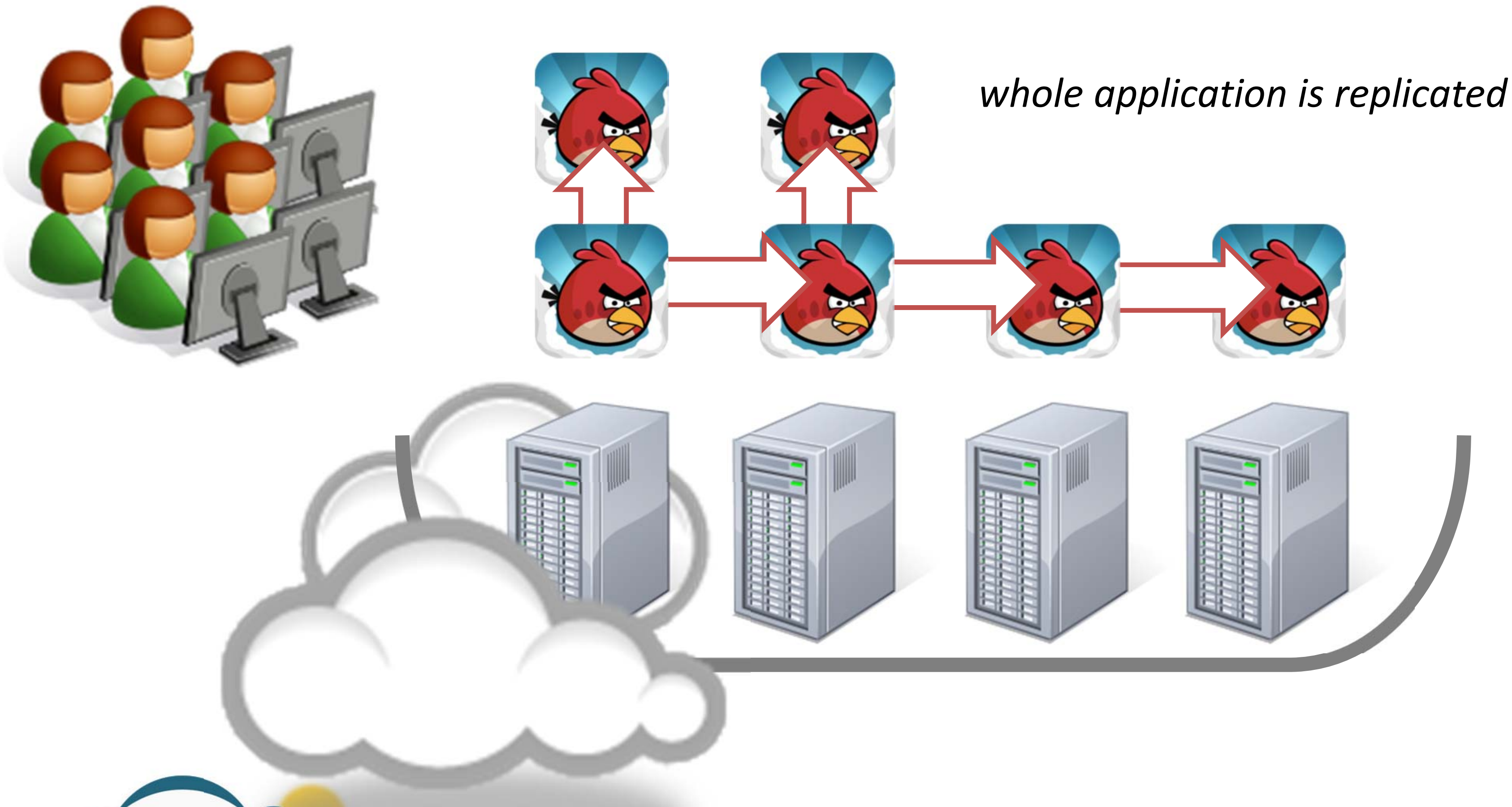
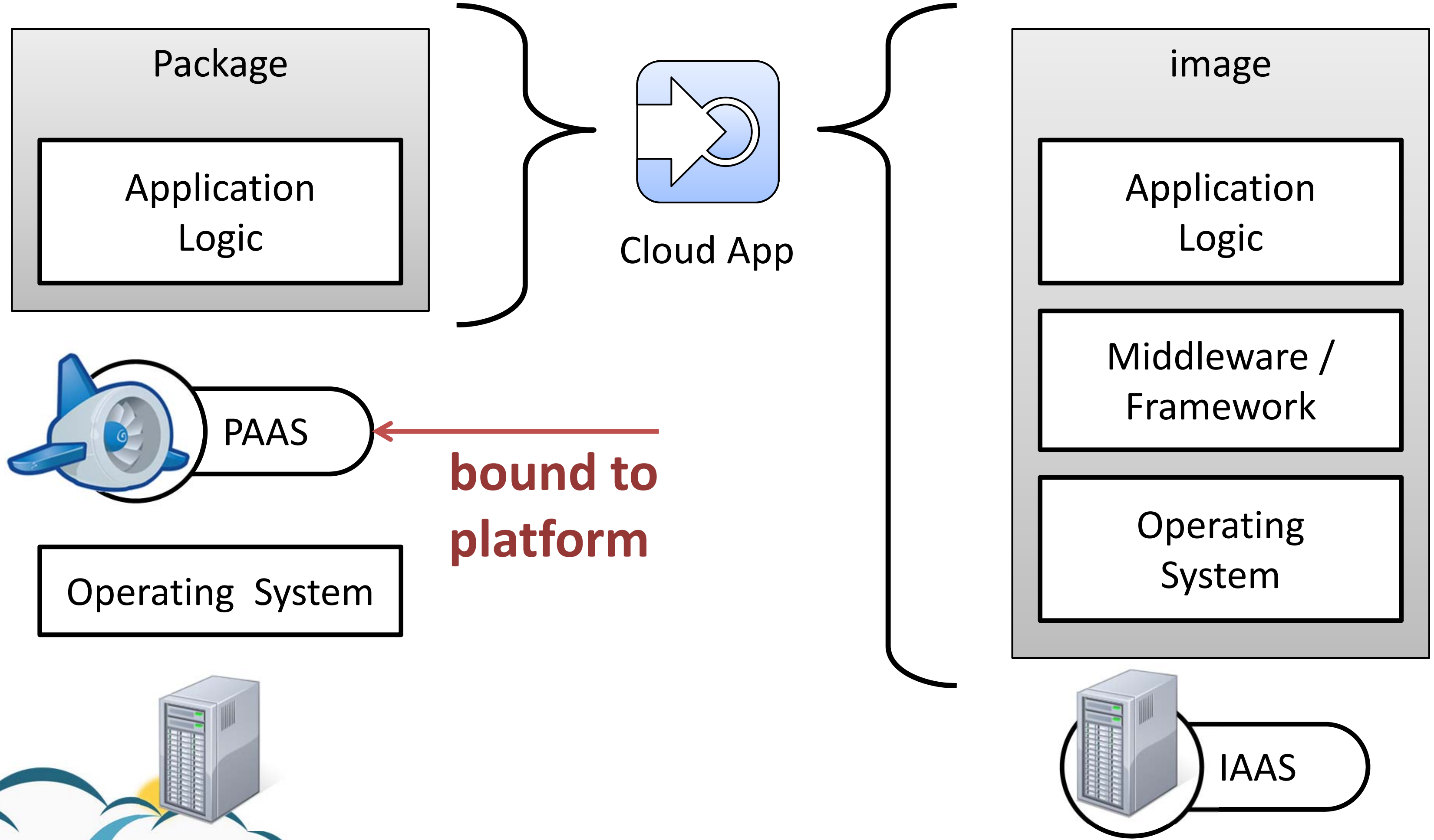


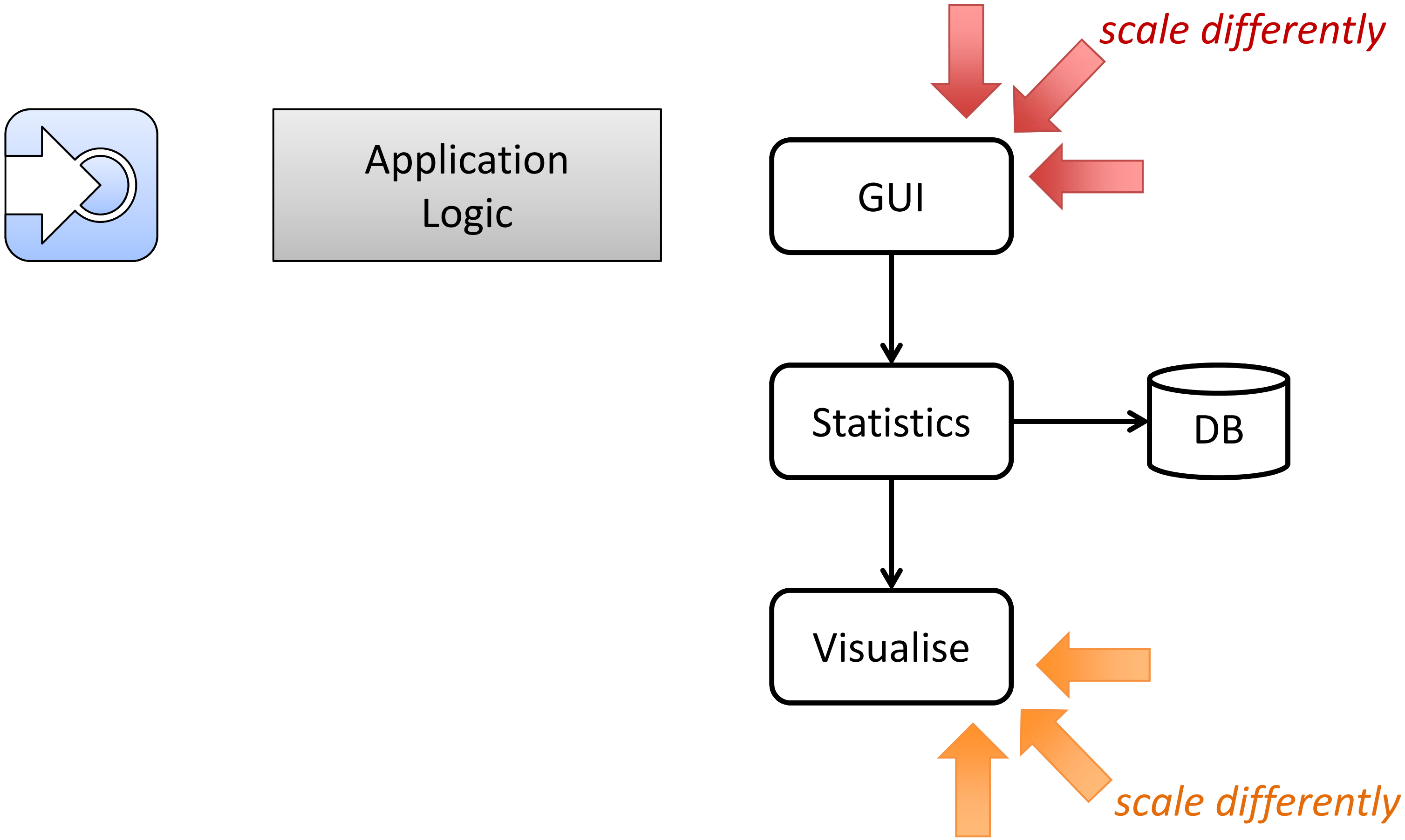
Current Cloud Solutions



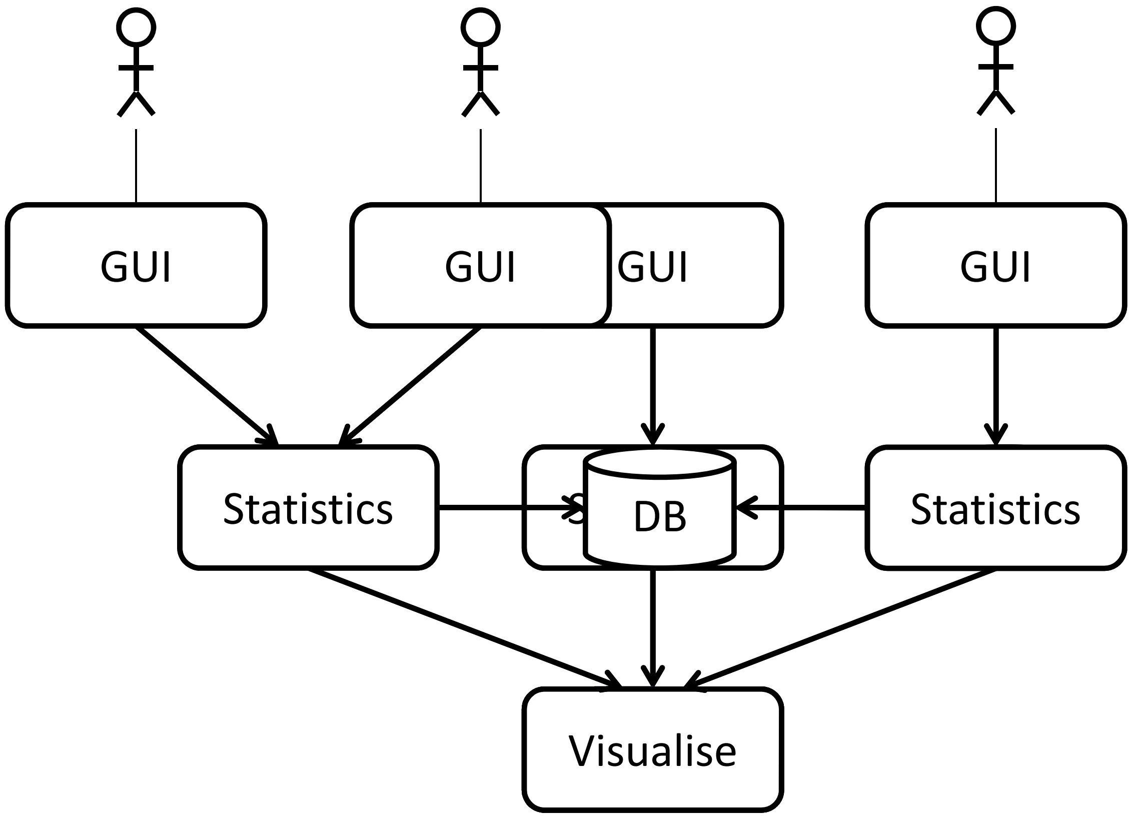
Behind The Scene



Behind The Scene (2)



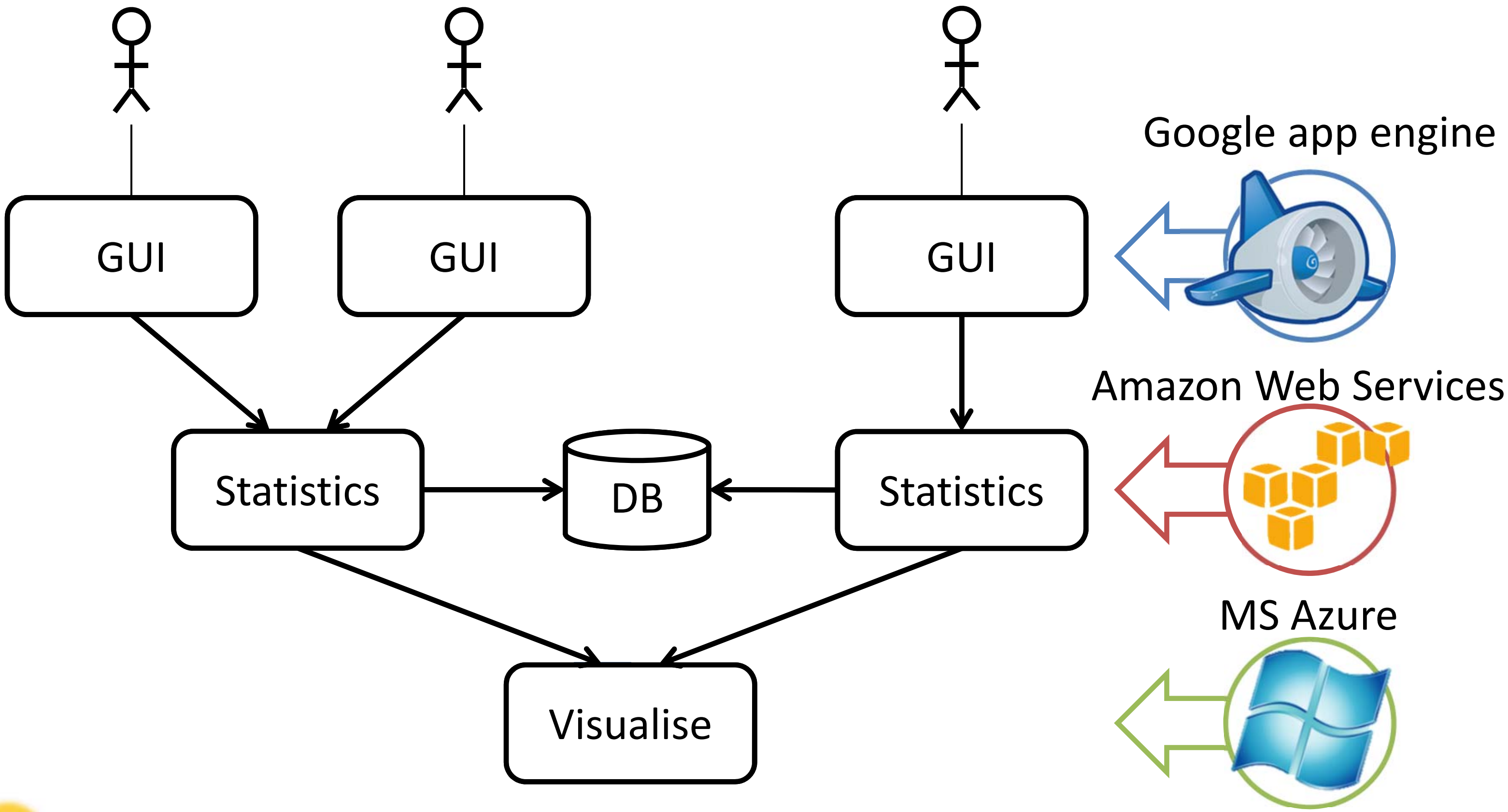
Theoretical Cloud Behaviour



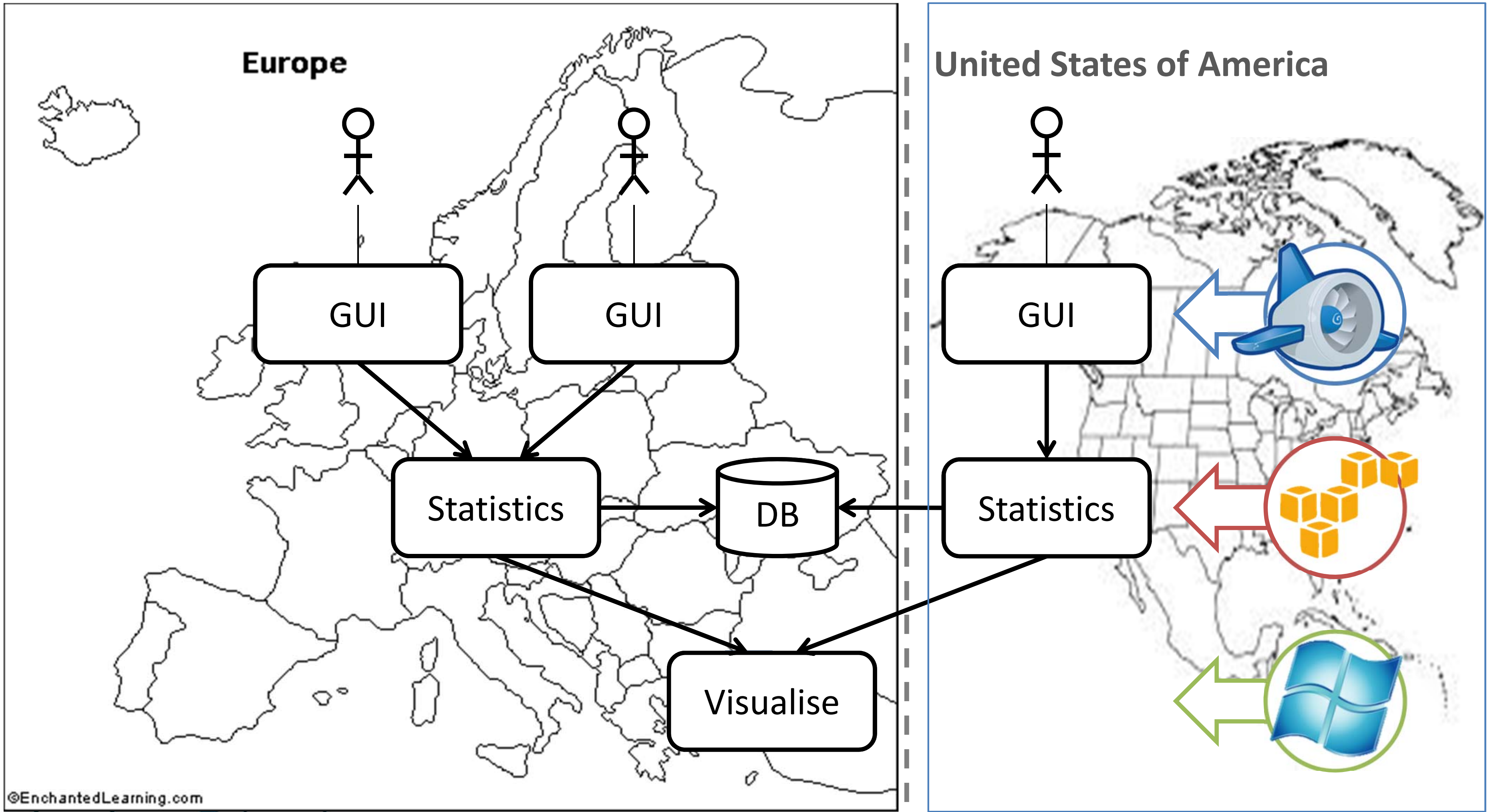
Problems

- Cloud infrastructure considers the application as a "block"
- No way of specifying the detailed scaling behaviour
- Little expertise and experience in clouds

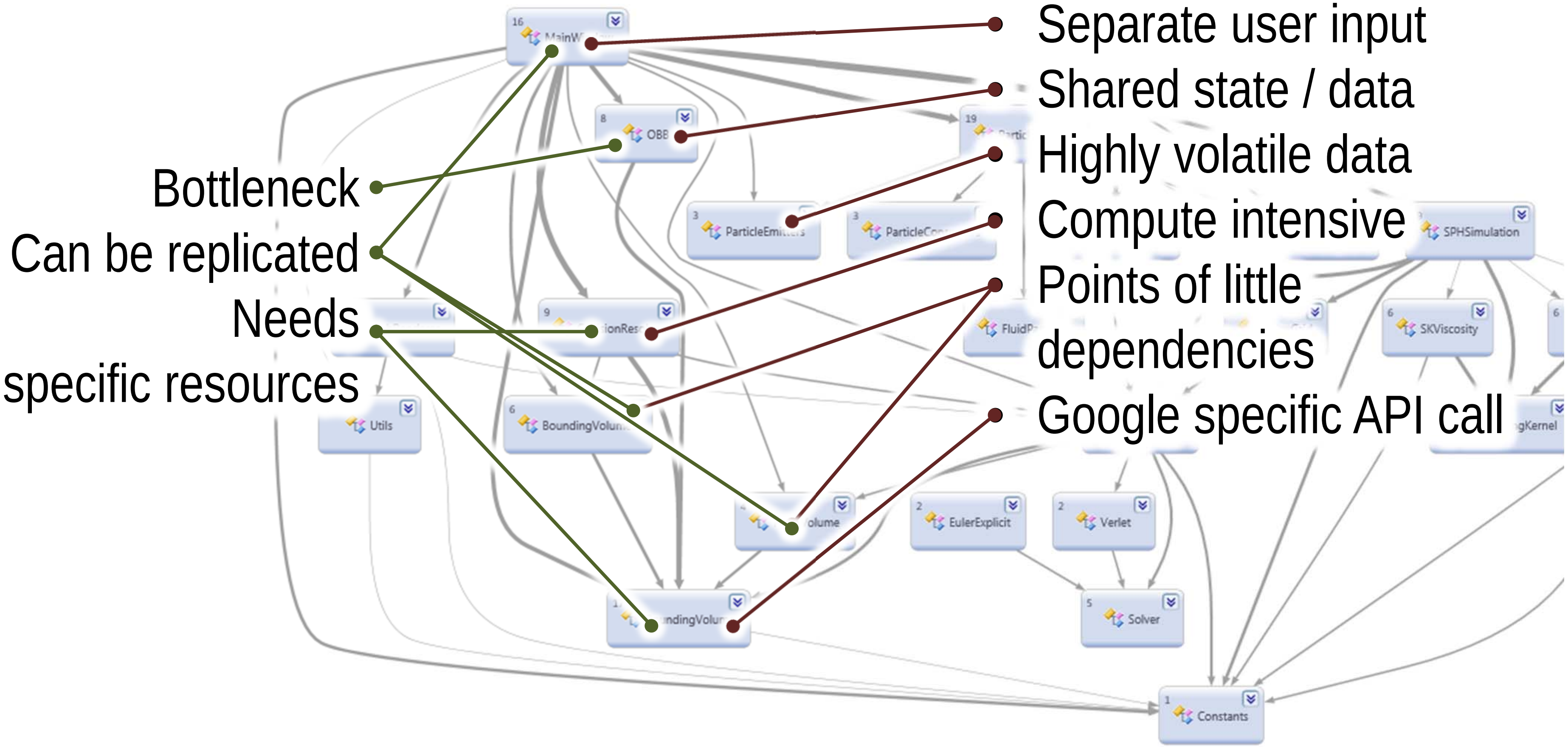
But There is More…



And Even More…



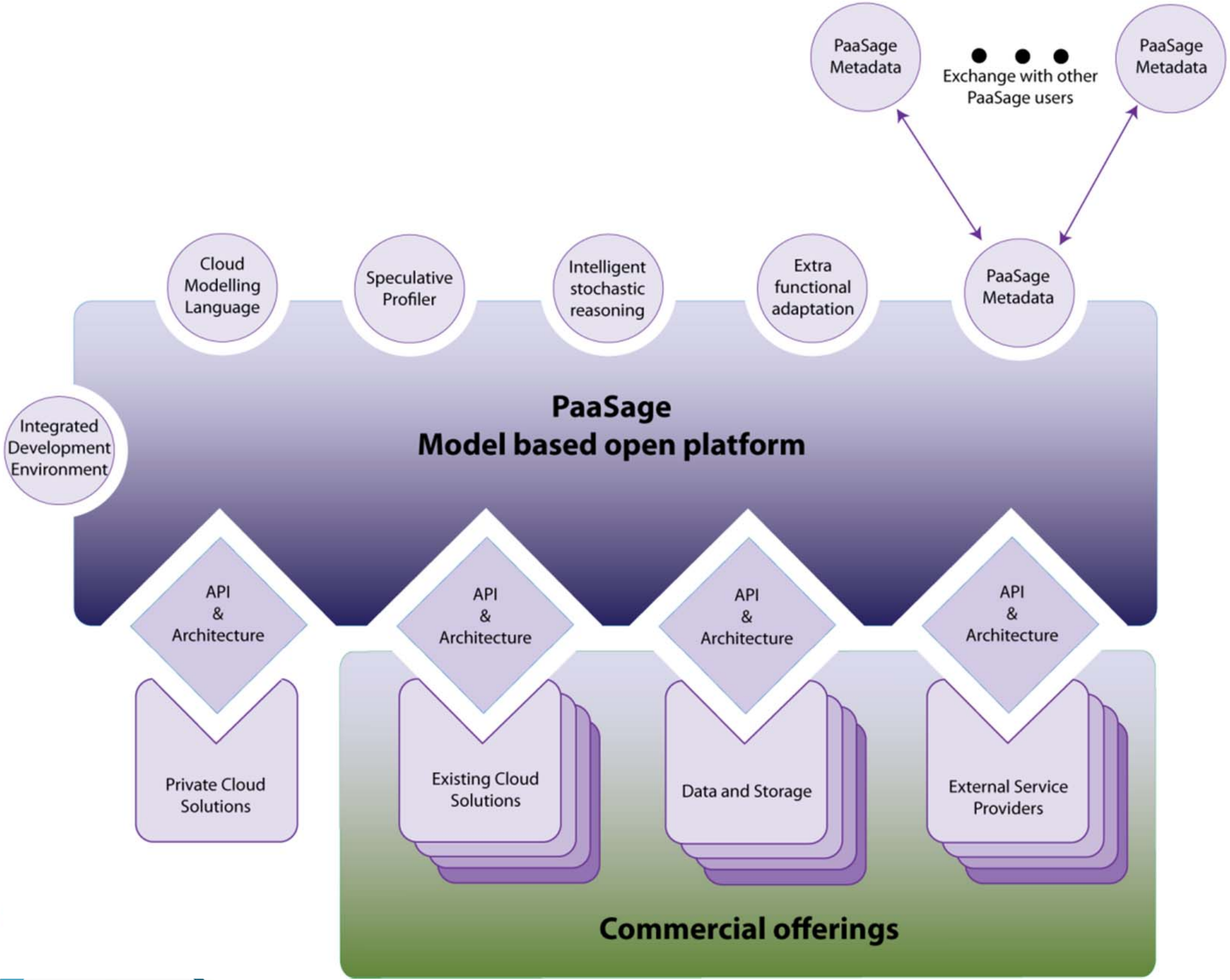
More Detailed Example



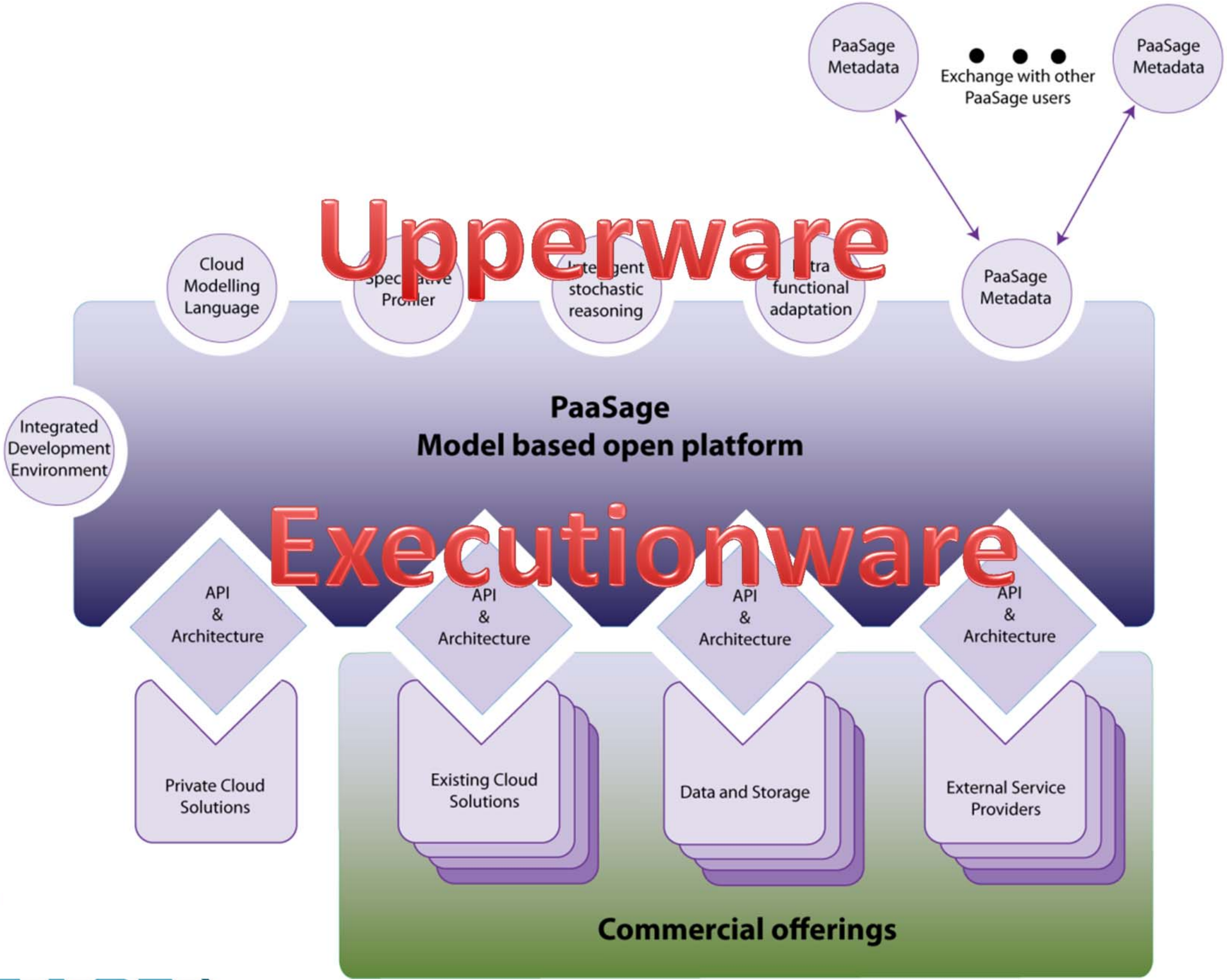
Problems, Problems, Problems

- Cloud infrastructure consider the application as a “block”
- No way of specifying the detailed scaling behaviour
- Little expertise and experience in clouds
- Resources of a single provider may not meet all needs
- Specialisation is not exploited

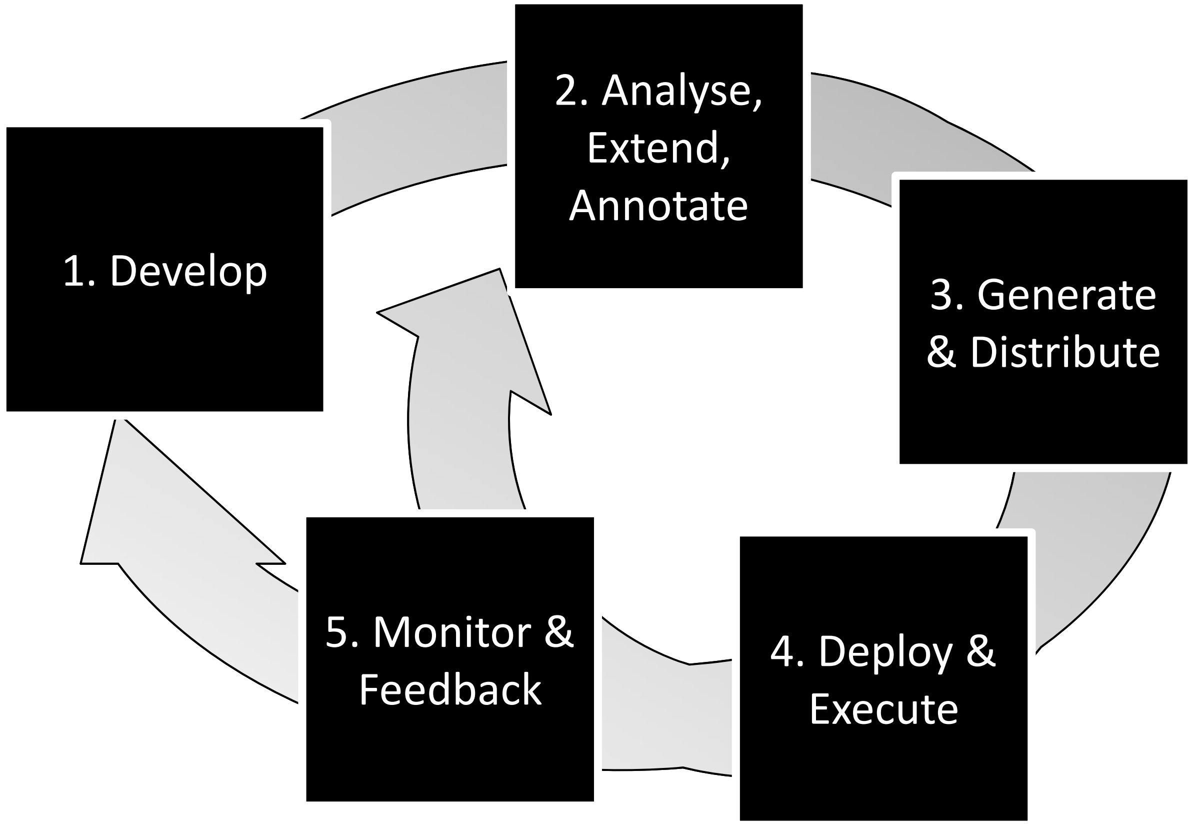
The Architecture



The Architecture

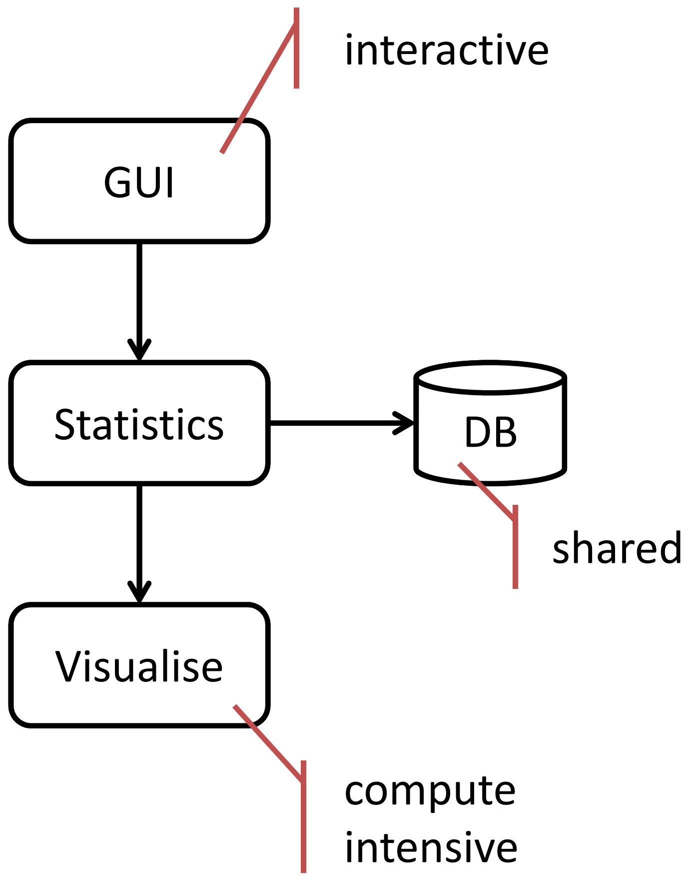


Ideal Application Lifecycle



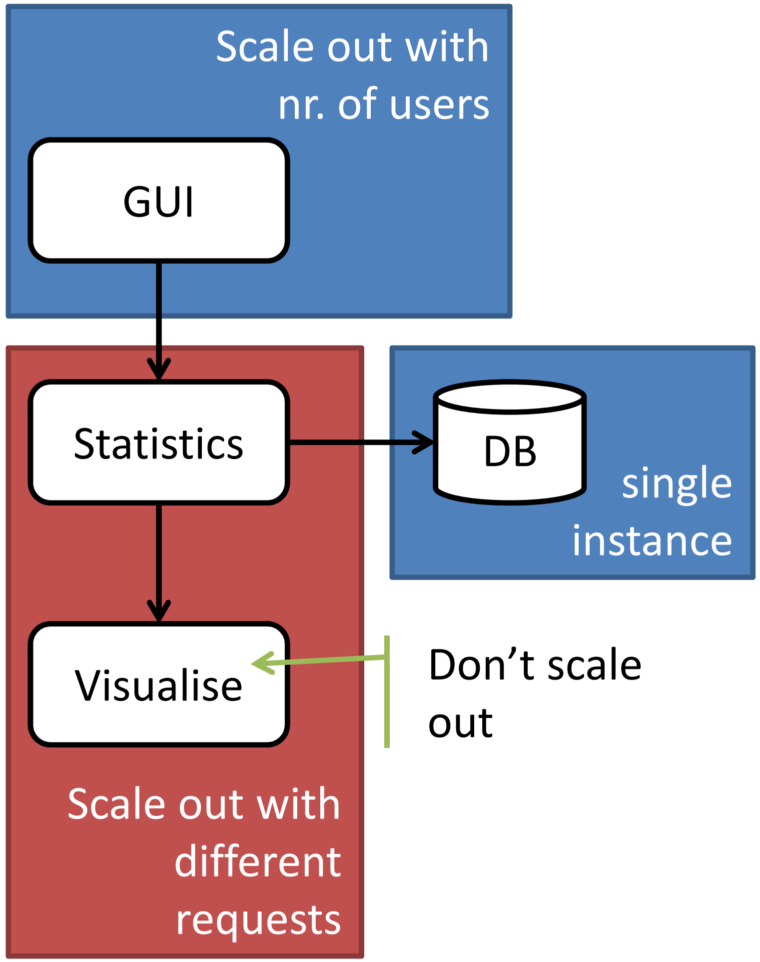
1 Development

- Develop your application as a *model*
- Each module exposes dependencies, requirements and scaling properties as metadata



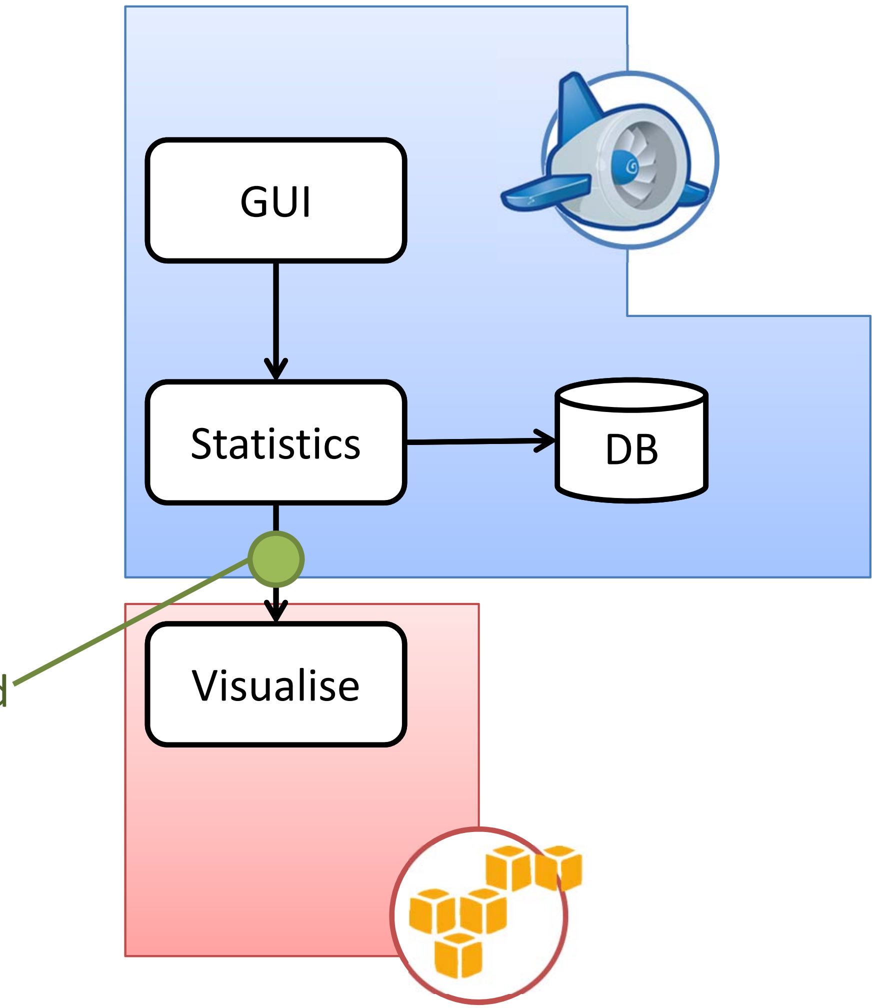
1 Development.Analysis

- PaaSage continuously evaluates these metadata
- And draws deployment / behaviour conclusions
- The developer can refine these conclusions



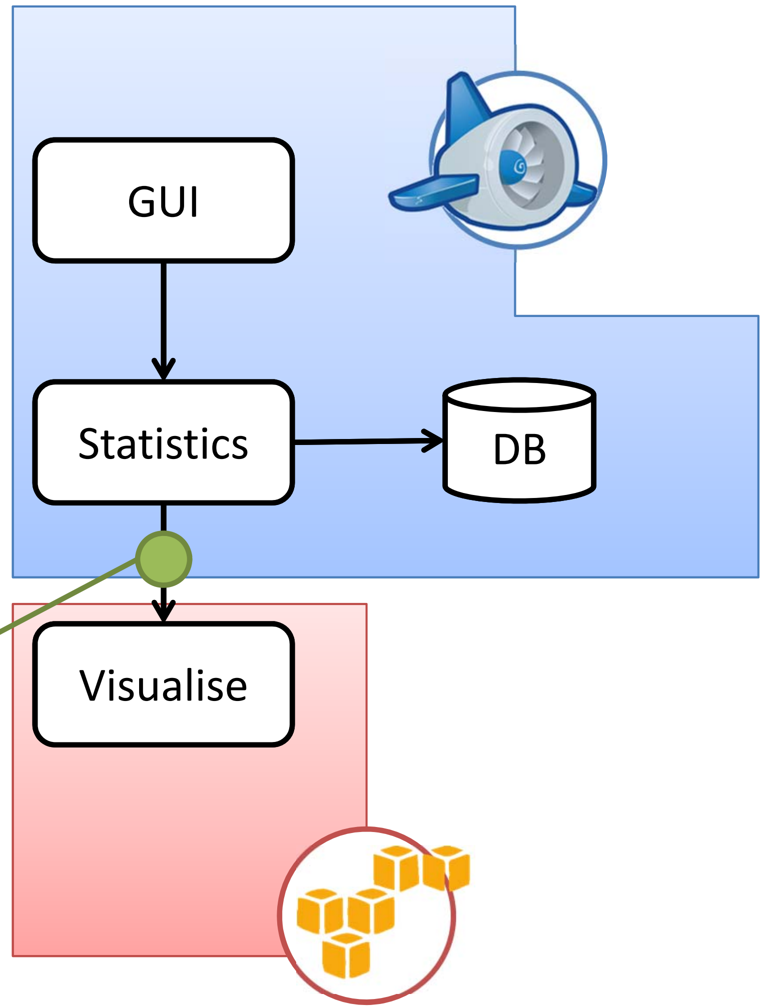
2 Deployment Support

- On basis of this information, PaaSage can suggest a configuration
- Which has implications on the implementation



2 Deployment Support

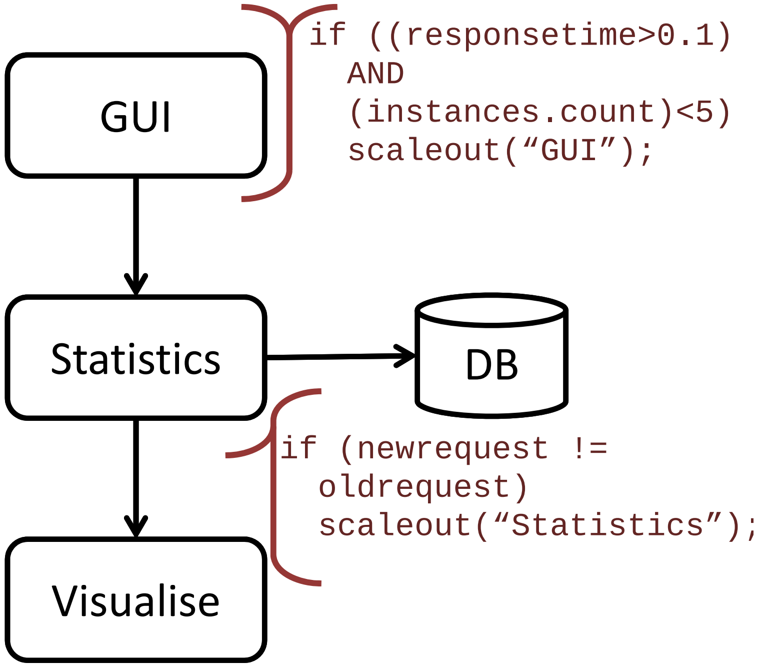
- PaaSage provides the necessary API to realise these updates



PaaSage.send(
PaaSage.identify(“Visualise”),
<dataset>)

3 Behaviour Control Support

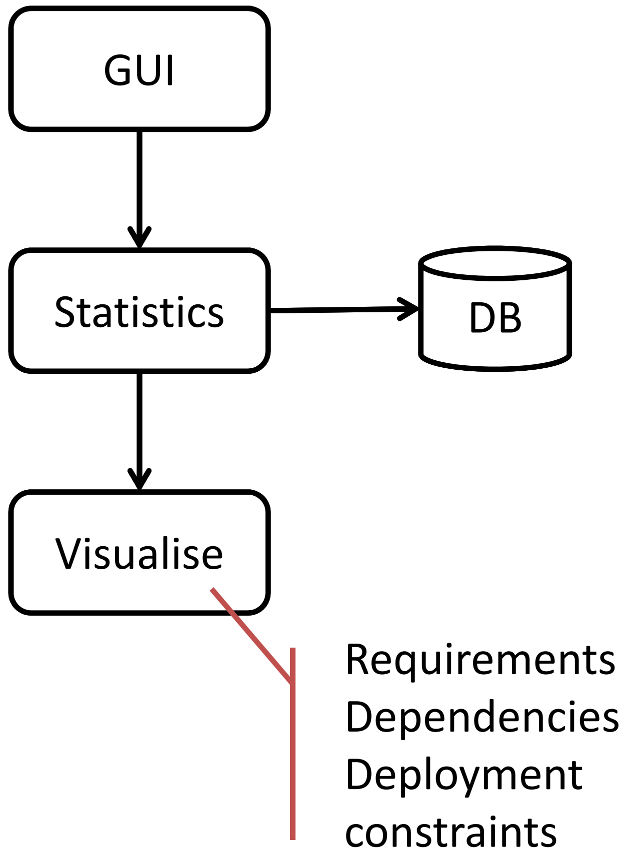
- PaaSage furthermore selects a set of common rules for fulfilling the (Cloud) properties
- Which again the developer may adjust



3 Behaviour Control Support

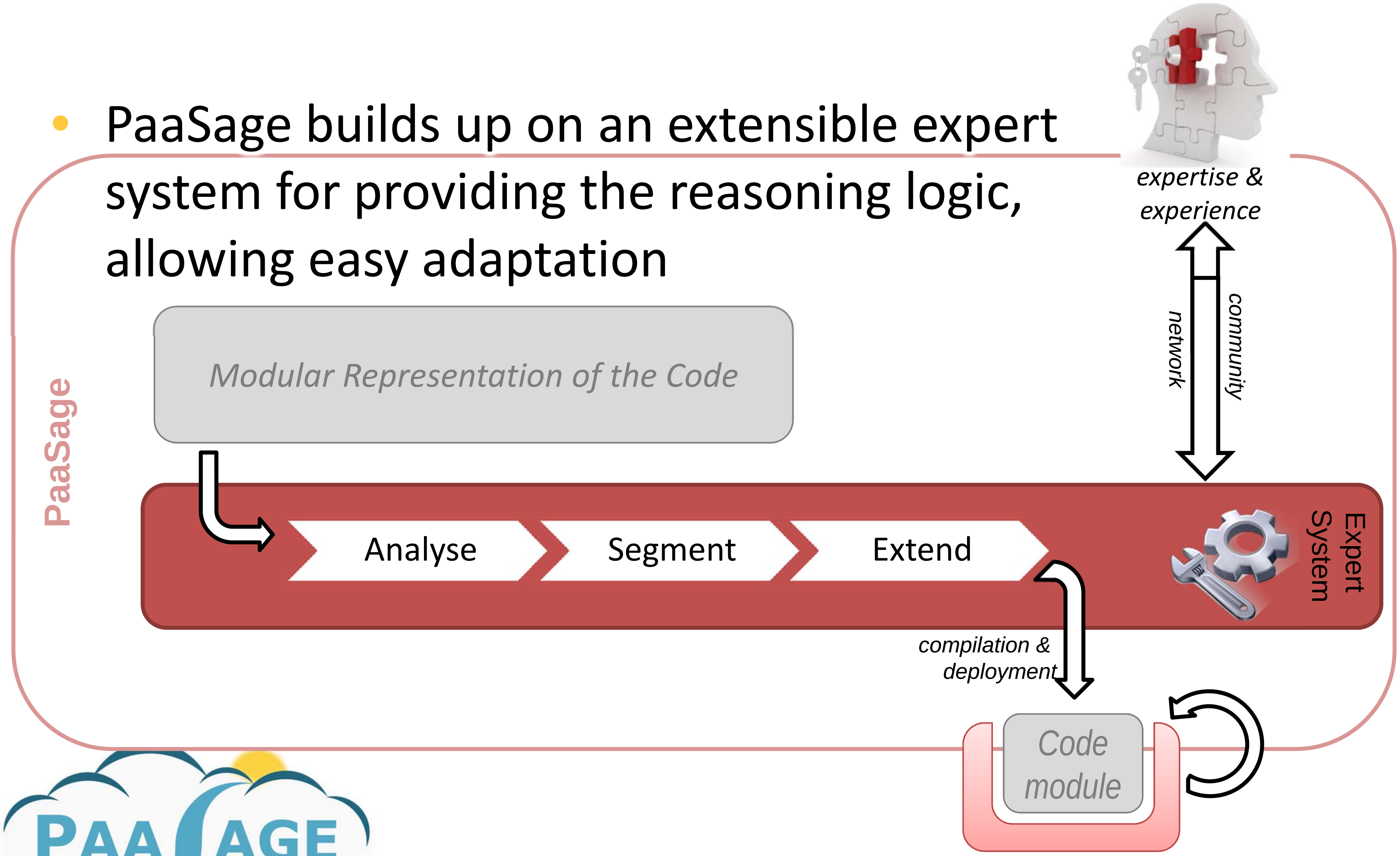
- The main task thereby consists in relating the
  - Constraints
  - Requirements
  - Dependencies

  with each other
- PaaSage performs no magic: if the dependencies cannot be resolved, the developer will be informed

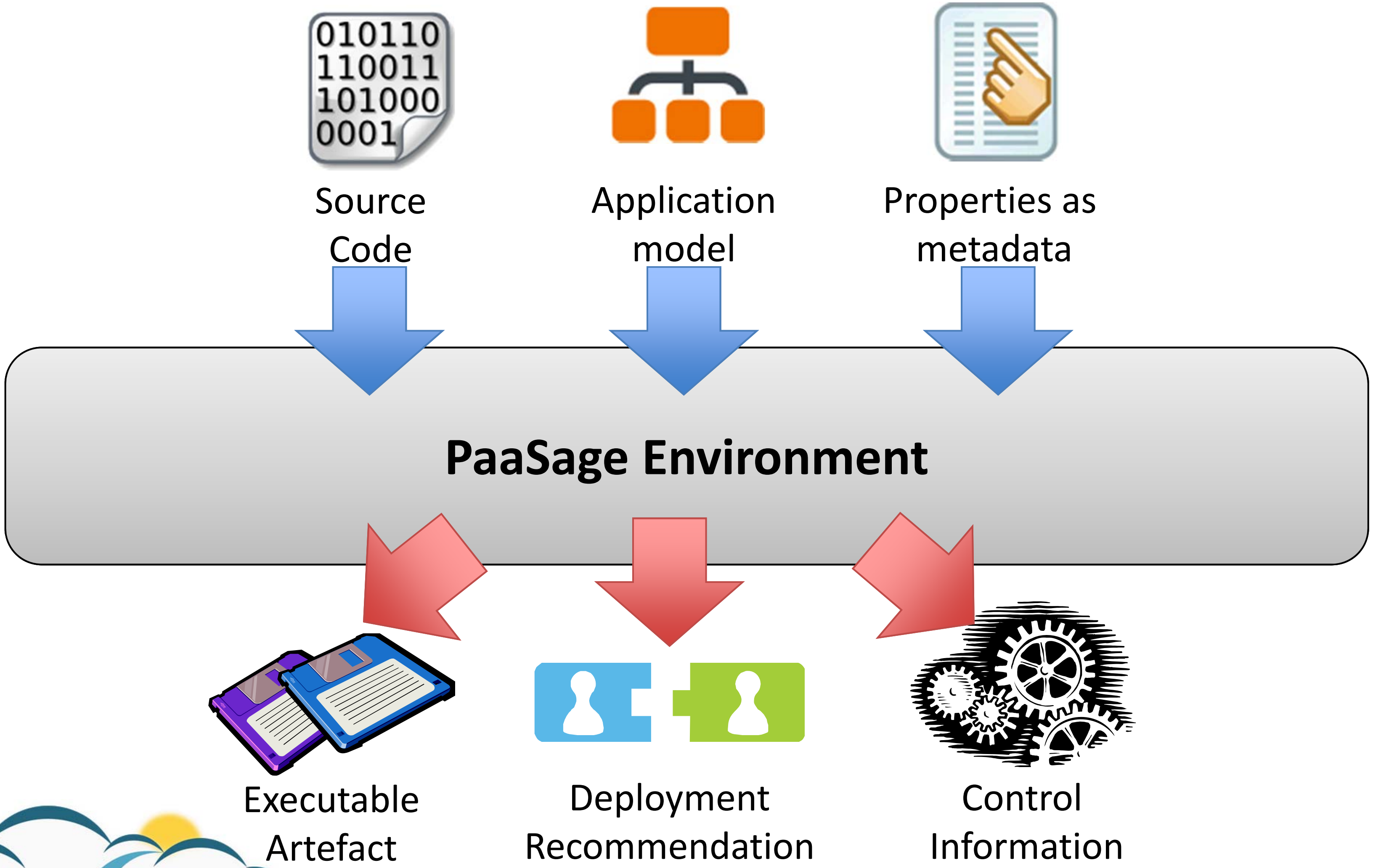


3 Behaviour Control Support

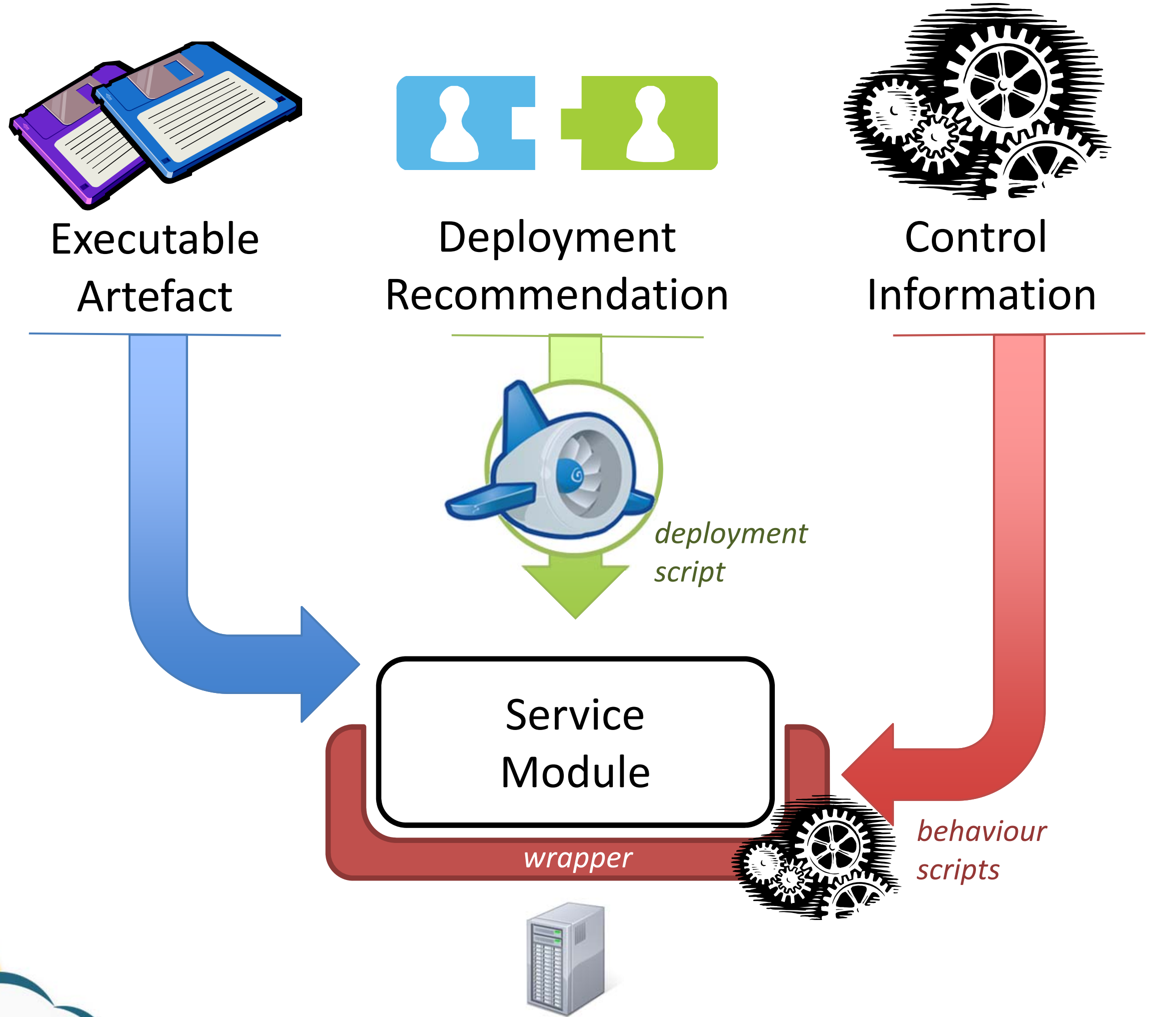
- PaaSage builds up on an extensible expert system for providing the reasoning logic, allowing easy adaptation



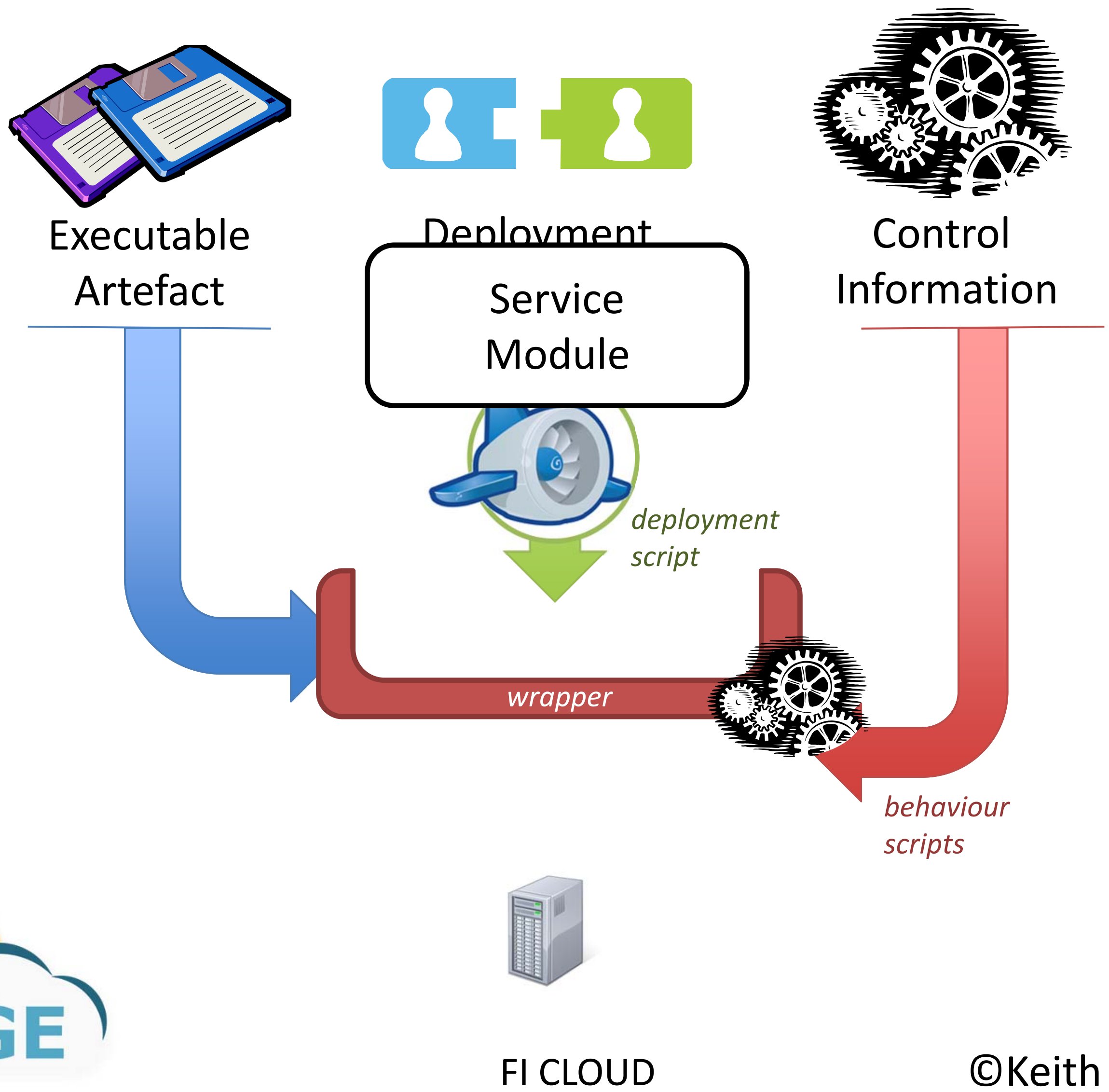
4 Generation



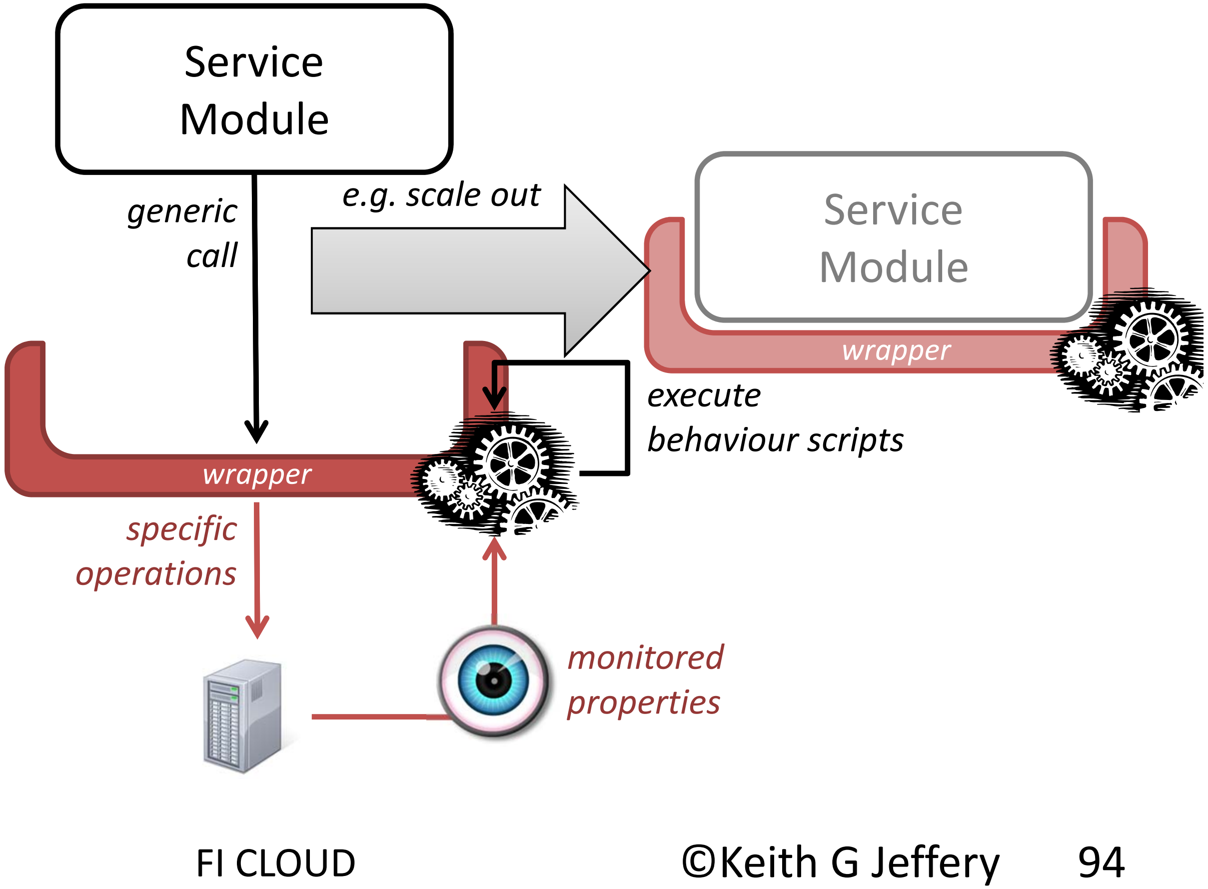
5 Execution & Adaptation



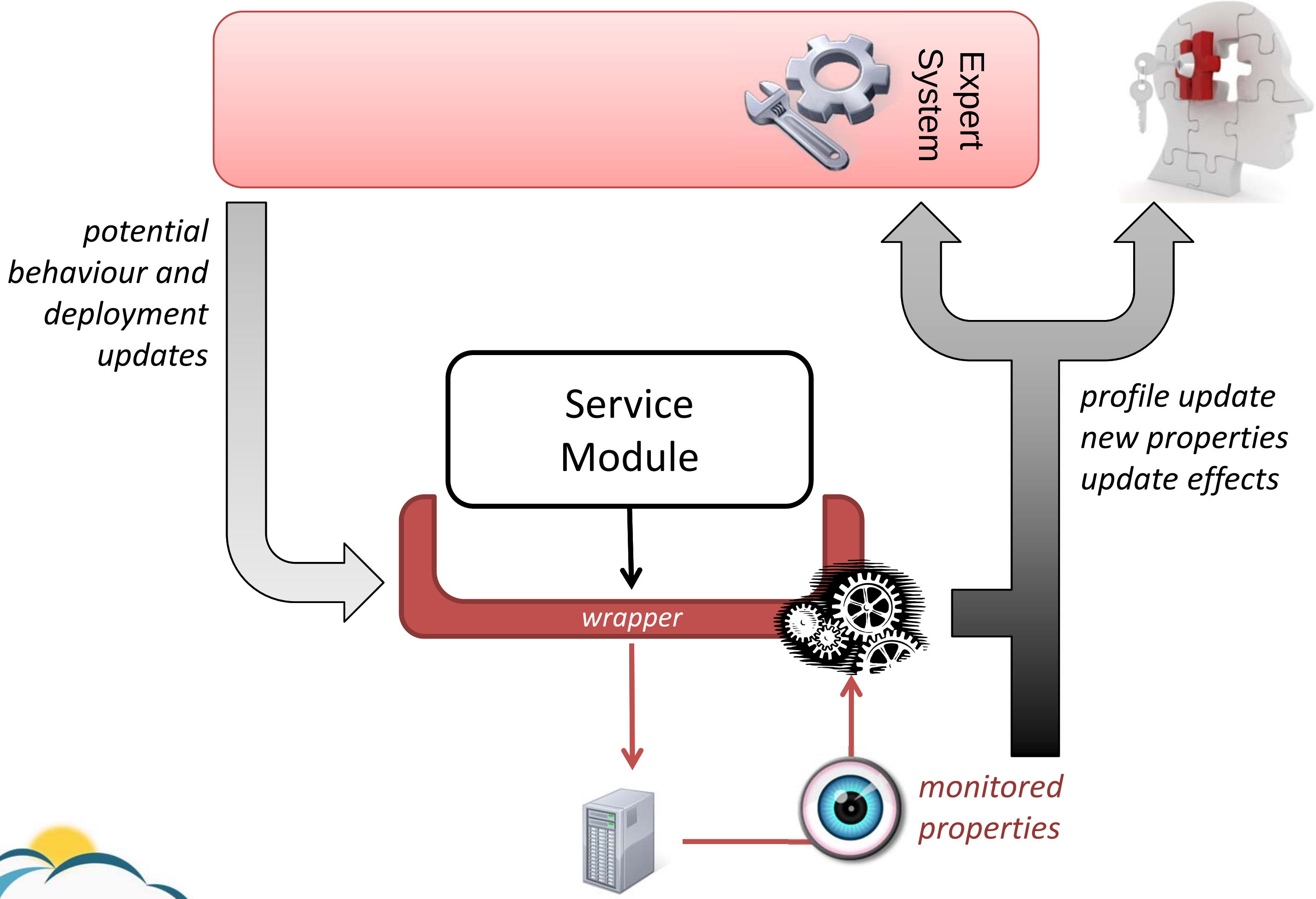
5 Execution & Adaptation



5 Execution & Adaptation



6 Feedback Loop



FI CLOUD

The Vision: The Models

Complete cohort of users, developers, sysadmins

User Model — interaction with data, processing, persons

Processing Model — providing what the user requires

representing the world — Data Model

representing ICT — Resource Model

Complete ICT environment

PaaSage

http://www.paasage.eu/

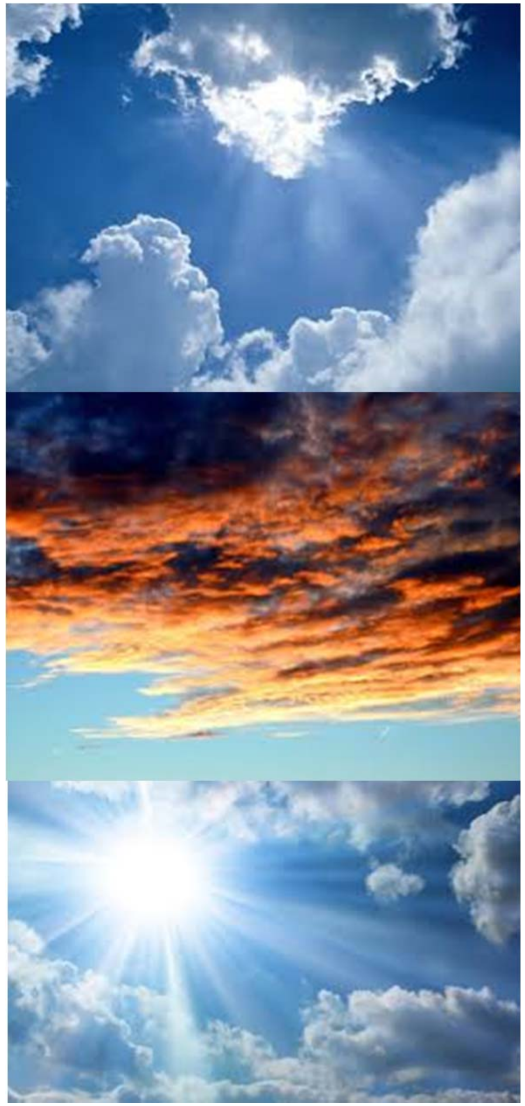
PaaSage is addressing the paradigm shift / leapfrog the competition aspects identified by the EC Expert Group

And the question is:

- Can the technique / architecture of PaaSage be applied with benefit in the FI/IoT environment?
- Can virtualisation and 'intelligent' (re-) deployment benefit sensor networks, mobile devices especially when interoperating?

Structure

- Introduction – Who?
- Setting the Context
- CLOUDs
- IoT/FI
- R&D in CLOUDs
- PaaSage
- Conclusion



Conclusion and a final challenge

- **YES THEY CAN !**

- But raise more questions / research topics:
  - Is the von Neumann architecture still valid?
    - Should we not optimise communications over other priorities?
  - Do we need to write programs?
    - Should we not just compose (dynamically – software 'robots') from services as components (like other branches of engineering)?
  - Will social / legal changes ever catch up with technology?
    - How does society and business control itself in the technological environment?

Challenges are what make life interesting.

Overcoming them is what makes it meaningful.

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PAASAGE