

Swarm computing, realisation of Computing Continuum

Atos Vision for Future Cloud

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Atos, Research & Innovation, Next Generation Cloud Lab



Agenda

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Computing Continuum vision

2

Associated Technologies & Trends

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**Open Research Challenges in Edge and Cloud
towards Swarm computing**

1

Computing Continuum vision

AtOS Computing Continuum

Cloud Service Integration - Multi-Cloud

intermediation and aggregation across diverse private and public clouds

very few actors are able to capture a **comprehensive holistic vision** embracing all the **opportunities** offered by this **cloud continuum** and even **fewer companies** are able to **provide solutions** able to make use of the **full technology spectrum**

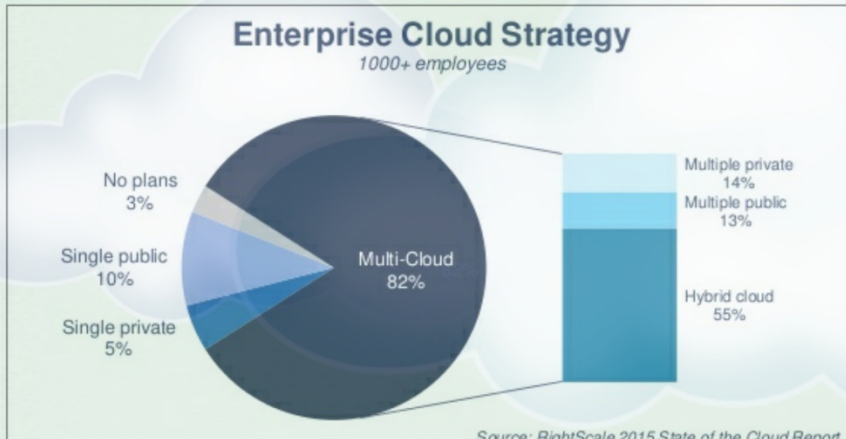
Reduced latency in large IoT scenarios

Edge local clouds



AtOS Computing Continuum

82% of Enterprises Want Multi-Cloud



Cloud Service Integration Multi-Cloud

intermediation and aggregation across diverse private and public clouds

Hybrid Cloud: Brokers, Marketplaces, Cloud Federation and Cloud Bursting

- ✓ Cloud **adoption** is **booming**.
- ✓ Underlying technologies are **mainstream** now, having reached a **high degree** of **maturity** and providing **responses** to **more complex scenarios**.
- ✓ **Cloud default platform** for start-ups and many enterprise organizations have already fully embraced the cloud model
- ✓ Even though the **maturity** of implementations is not always at the same level and there remains **uncertainty** about the appropriate use of **Public, Private and Hybrid cloud models**.

AtOS Computing Continuum

Edge Computing

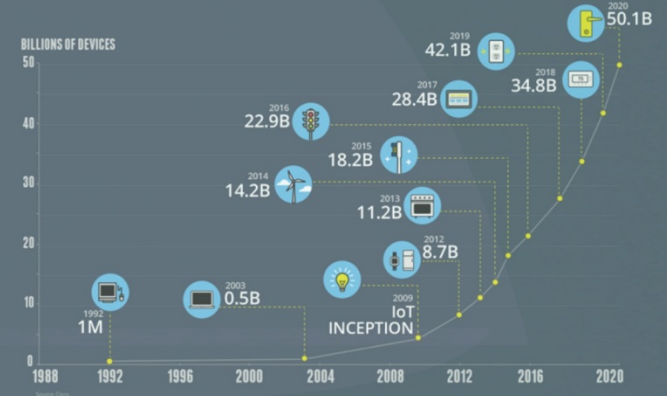
Computing and Storage
Virtualisation and Multi-tenancy
Reduced latency in large IoT
scenarios

Cloud Computing at the Edge of the network



GROWTH IN THE INTERNET OF THINGS

THE NUMBER OF CONNECTED DEVICES WILL EXCEED 50 BILLION BY 2020



- ✓ **organizations** that **aspire** to lead the future digital business are **pioneering solutions** based on **connected devices** and **IoT** related technologies.
- ✓ **Maturity, standards** and **adoptions** are in **early stages** even though there is a common consensus that these technologies as the **next big thing**
- ✓ **investments** and **experimentation** **growing exponentially.**

CLOUD CONTINUUM, AN ENABLER FOR SWARM COMPUTING





Swarm computing combines **network** and **cloud principles** in order to **create an on-demand, autonomic and decentralised computing and storage management layer** that **transparently interoperates** among **diverse and disperse Edge and cloud models** and **typologies**.

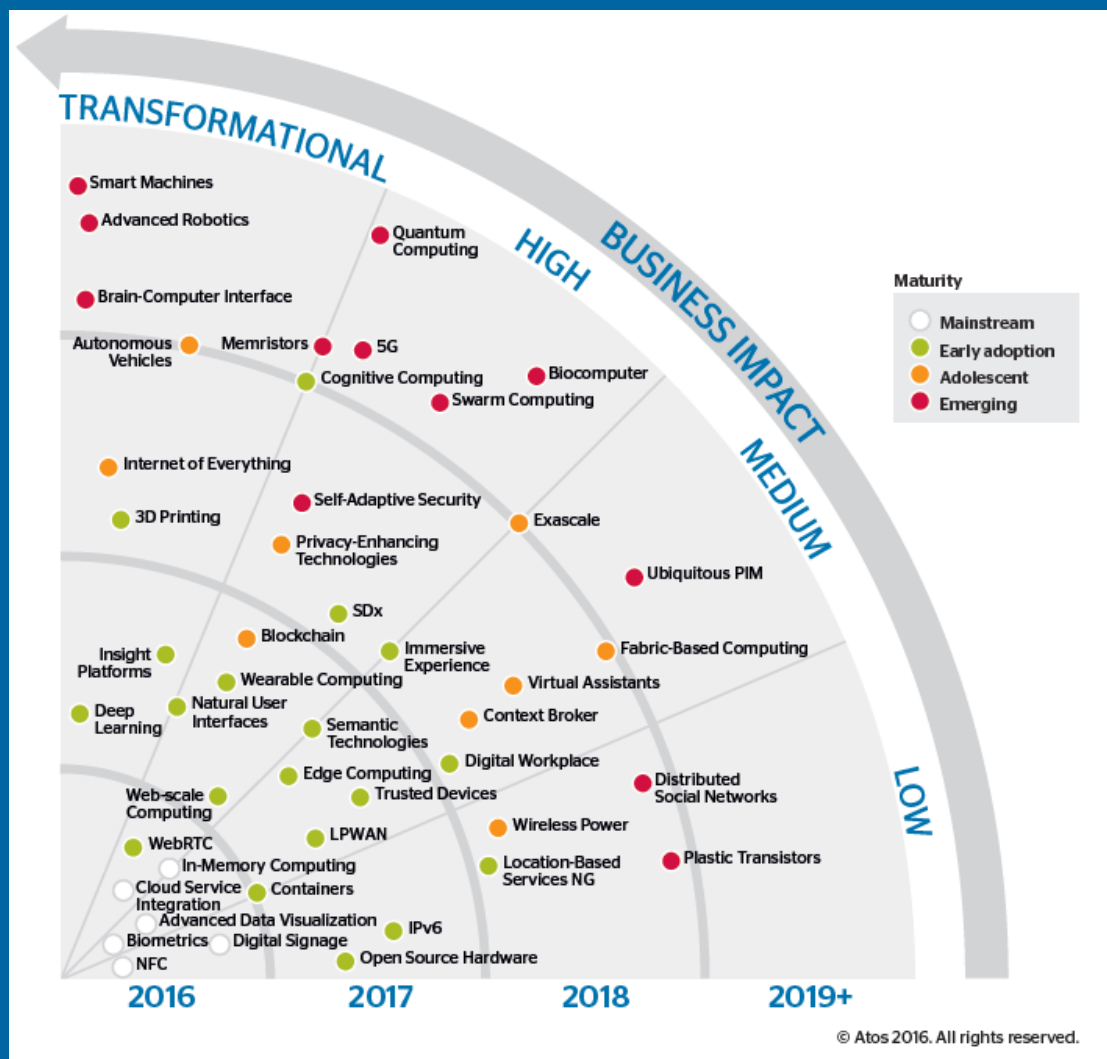
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Associated Technologies & Trends

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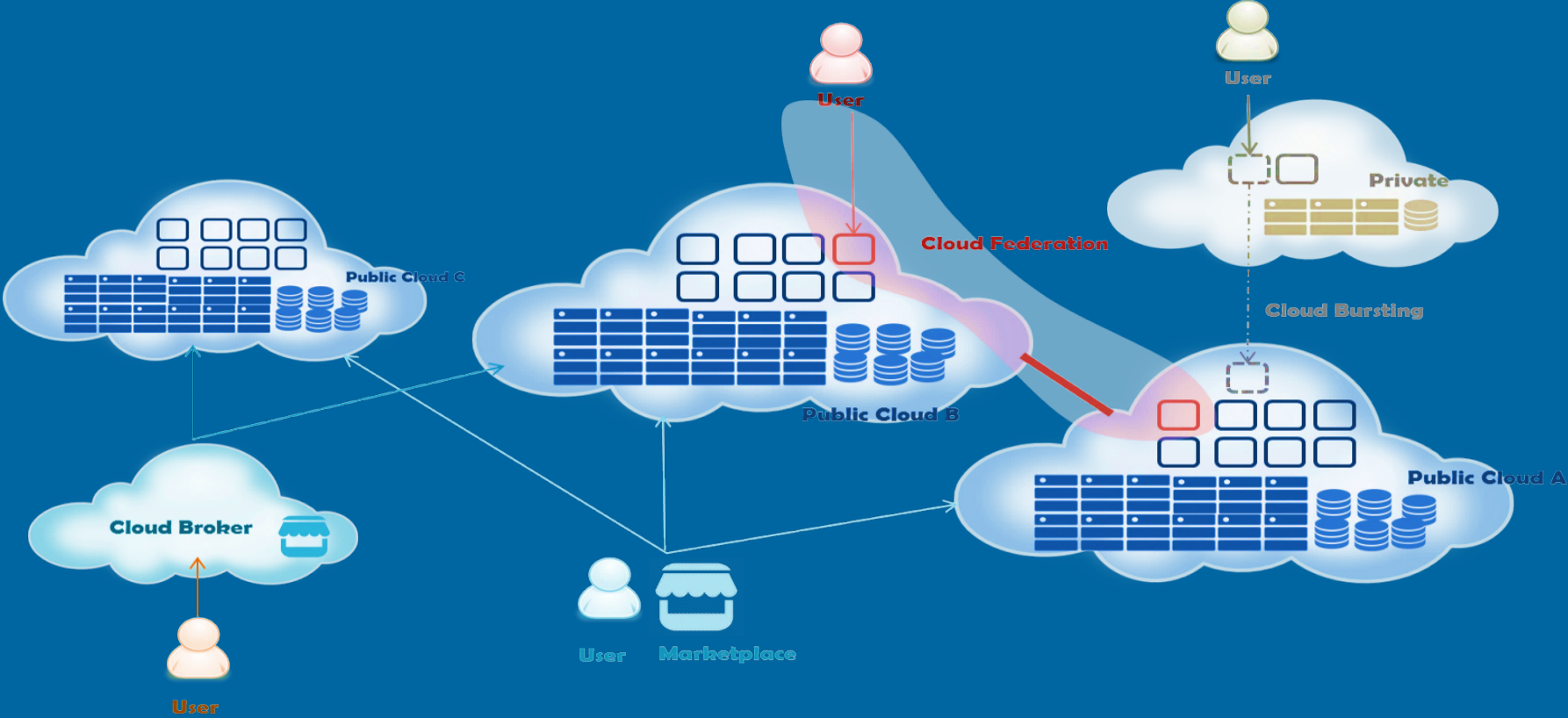
-  Cloud Service Integration
-  Edge Computing
-  Cognitive Computing
-  Internet of Everything
-  Smart Machines
-  Swarm Computing



Cloud Service Integration

- ▶ The **new computing continuum** will be a **heterogeneous environment** based on the **decentralization** and **federation** of **diverse computing entities** and **resource typologies**.
- ▶ These will include **multi-cloud (and cloud federation) models** with their diverse, **decentralized** and **autonomic** management and **hybrid cloud models** that **cross boundaries** between **internal** and **external cloud services** or between **public, private** and **community** providers.
- ▶ Cloud Service Integration (CSI) provides a **flexible means** for assembling these various cloud-based elements in support of **business process** that **transverse IT domains**.
- ▶ Compute workloads are deployed across multiple **cloud environments** to provide an **optimal delivery model**.

Cloud Service Integration - Multi-Cloud Scenarios



Cloud Service Integration - Multi-Cloud Impact

- ▶ Helps companies **balance functionality, flexibility and investment protection**
- ▶ **Reduces cost** by eliminating the need for hardware to **absorb peak demands, reducing overall management cost and energy consumption**
- ▶ **Accelerates** computing **resource delivery** while improving resource availability and **optimizing resource utilization**
- ▶ Helps small and medium companies **handle peak-loads**, acquiring additional capacity as and **when needed**
- ▶ **Brings workloads closer** to where **demand** is, eliminating unnecessary **latency**
- ▶ **Ensures compliance** with national regulations when customers have specific restrictions about the legal boundaries in which their data and application can be hosted

Cloud Service Integration Issues

- ▶ **Compatibility** across services is still an **open issue**, compromising further advance of inter-cloud service provisioning. **Cloud market leaders** are **yet** to widely adopt any **standardization efforts**, but **multi-cloud** may be the **market force** that pushes that **adoption**, breaking down current **vendor lock-in**.
- ▶ Multi-cloud environments **increase** the complexity of **service level agreements** since providers rely on diverse services from a more complex cloud ecosystem. Existing contracts will need to be analyzed and extended so **chains of contractual relationships** can be **automatically established across multiple and heterogeneous cloud providers**.
- ▶ Multi-cloud environments will need **virtual networks** to be set up across multiple cloud providers. **Yet poor network performance** is a **roadblock** for wider cloud adoption, while cloud federation requires extensions to the concept, **techniques** and **primitives** of **cloud networking**.
- ▶ The **constant changes in security parameters** enabled by dynamic multicloud management models is **amplifying current security concerns**.

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Cloud Service Integration

Edge Computing



Edge Computing

- ▶ The growth of the **Internet of Things (IoT)** and the emergence of ever-richer cloud services together **call for data to be process at the edge of the network.**
- ▶ Edge computing is also referred to as fog computing, mesh computing, dew computing and remote cloud.
- ▶ It **moves applications, data and services away** from the **centralized model of cloud computing** to a more **decentralized model** that **lies at the extremes of the network.**
- ▶ **Ubiquitous** (and sometimes **autonomous**) **devices** — including the laptops, smartphones, tablets and sensors that may not be continuously connected to the network — **communicate** and **cooperate among themselves** and with the **network** to **perform storage** and **processing tasks** without the intervention of third-parties.
- ▶ Edge computing **covers a wide range of technologies:** from wireless sensor networks and mobile data acquisition to **distributed peer-to-peer ad-hoc networking** and **processing** and more.

Edge Computing Impact

- ▶ Brings **computation and storage closer to the source of the data**, ensuring the results of analytics and other processing are rapidly available and highly accessible to the systems that need most them
- ▶ **Addresses latency issues** detected in large **Internet of Things (IoT)** scenarios
- ▶ Conserves **bandwidth and reduces privacy and security risks** by eliminating **unnecessary network transmission** as an increasing number of 'things' and connected devices generate growing volumes of data
- ▶ **Lightens the load of centralized cloud servers**
- ▶ Expected to enable a **broad spectrum of use cases and applications** for which **traditional cloud computing** is not **sufficient**

Edge Computing Issues

- ▶ **Applications** written for an edge scenario will often need to work on **heterogeneous environments**.
- ▶ Data reported from different things may come in a **variety of formats**. **Standardization** is needed to enable **interoperability among devices** and sensors **within both edge and traditional cloud environments**.
- ▶ The potentially thousands, or even millions of small devices and sensors, in edge computing set-ups will require a **new style of device management**. This may potentially need to be **decentralized** and **able to scale to degrees unprecedented** in today's existing **cloud architectures**.
- ▶ Envisaged as multi-tenant, edge computing set-ups will require specific **isolation mechanisms** to **avoid security and privacy concerns**.

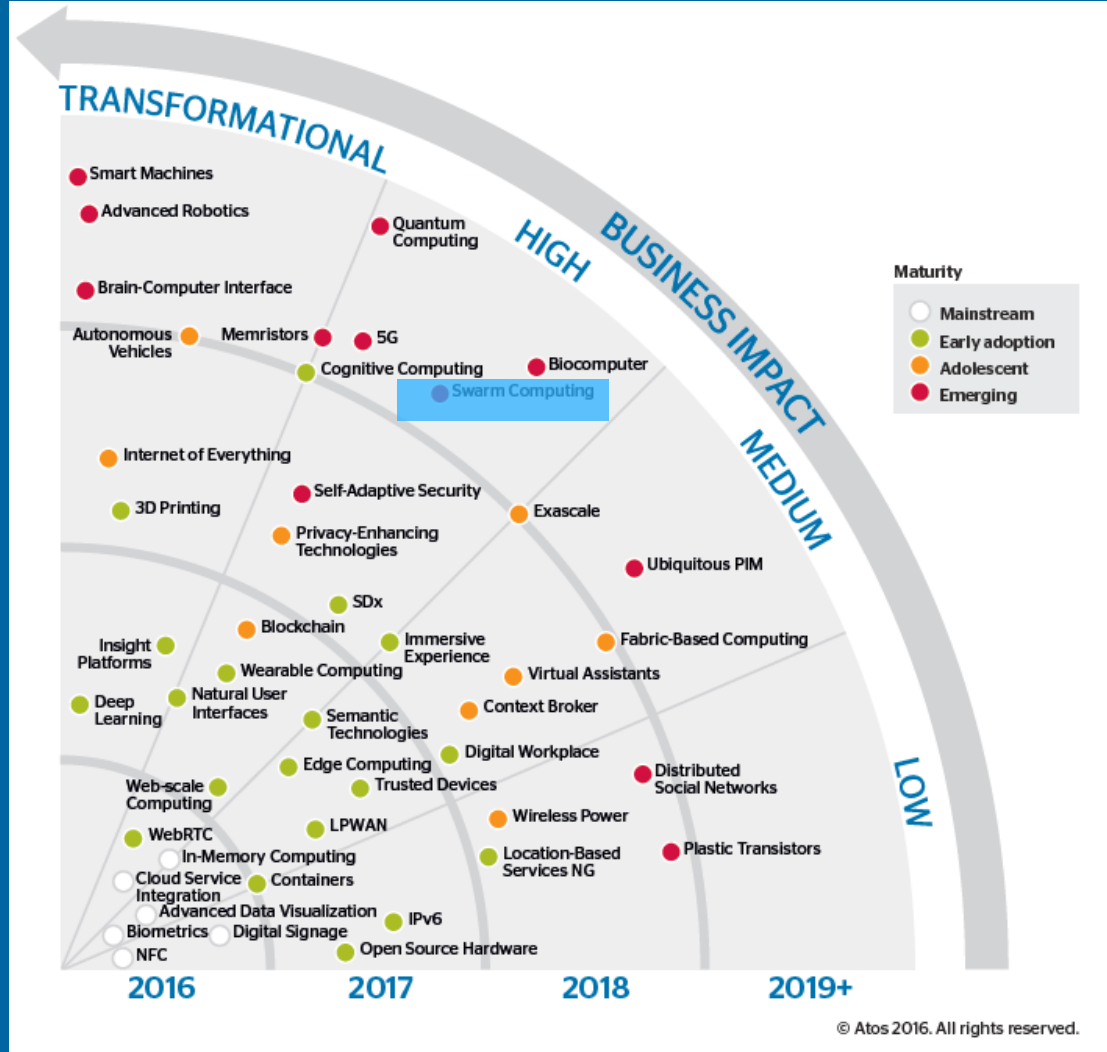
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Cloud Service Integration

Edge Computing

Swarm Computing



Swarm Computing

- ▶ **Swarm computing** refers to **massively distributed, self-organizing systems** of agents that **work collaboratively towards a defined outcome**.
- ▶ Each **agent** within the **system** has a **simple** set of **rules** to **follow** and **only interacts** with its **local environment**.
- ▶ The **aggregate behaviour** of the **agents** leads to the **emergence** of **'intelligent' global behaviour**.
- ▶ With the **number** of **nodes** comprising the **Internet of Everything (IoE)** predicted to **rise** and **many individual nodes likely** have **limited compute capabilities**, each would be **complimented** by **connection** to other **objects** in a **community** — thus **creating an IoE swarm**.

Swarm Computing Impact

- ▶ Creates a **dynamic eco-systems** of **cyber-physical devices** and **clouds**, **each adding** to the **collective capability** and **insight**
- ▶ Allows **operations** and **interactions** to **adapt according** to **context**
- ▶ Improves **efficiency** and **reliability** of **service provision** through:
 - **Enabling ad-hoc collaborations**, which help **built service networks**
 - **Optimizing delivery schemes** and **communication patterns**, which **allow information** and **services** to be **shared** and **exchanged**
 - **Creating** reliability and **dependability** from **volatile resources**, which help **manage uncertainty**
- ▶ **Allows** work to be **distributed** across **simpler devices** (or robots)
- ▶ **Complements** other **forms** of **artificial intelligence**
- ▶ **Provides** a **significant** step **toward massively distributed computing models**

Swarm Computing Issues

- ▶ **Agent-based programming** is **complex** and **skilled practitioners** are not **easy to come by** at this present time.
- ▶ **Integrating swarms** with other **centralized control mechanisms** is also **complex**.
- ▶ **Security** is a **huge concern**, especially if individual robots within a swarm are under the **primary control** of **different individuals** or **organizations**.
- ▶ **Communication protocols** need to be **standardized** to **enable flexible** and **dynamic interaction**.
- ▶ There is a **possibility** that **non-deterministic behaviours**, including **unexpected** or **out of control 'emergent' behaviours**, may emerge.
 - **Swarm viruses**, where **swarm behaviours** are **influenced adversely** by rogue **components**, may also emerge.
 - These **would** have **huge implications** in **use cases** such as driverless vehicles.

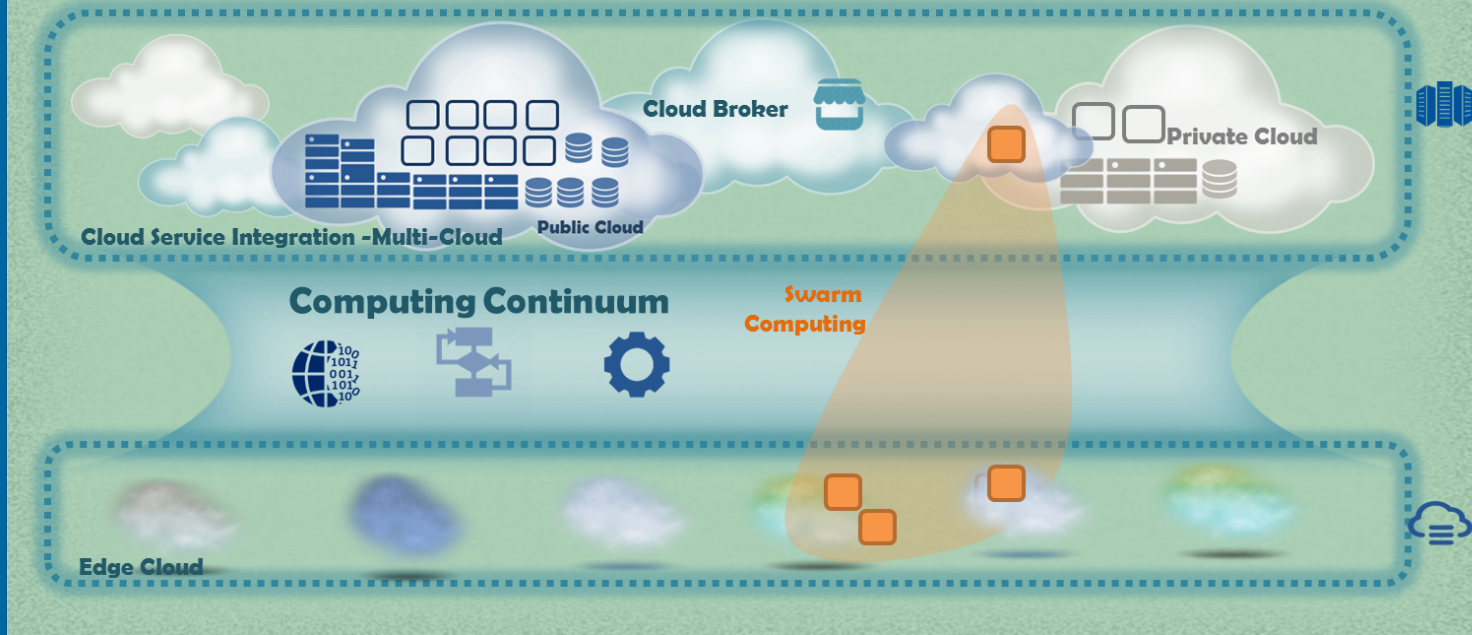
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Open Research Challenges
in Edge and Cloud towards
Swarm computing

Swarm Computing requirements

- ▶ **Swarm hyper distribution** of computing will have to enable **cloud computing continuum** scenarios to **consider**
 - **interoperability**
 - **portability**
 - **elasticity**
 - **self-organisation**
 - **self-management**
 - **self-healing**
- ▶ Across **many** and **heterogeneous resources**
- ▶ in **Edge clouds, private enterprise clouds, aggregated cloud models** and **large Cloud set-ups**

Atos Computing Continuum towards Swarm




Service Management / Advanced Cloud Capabilities

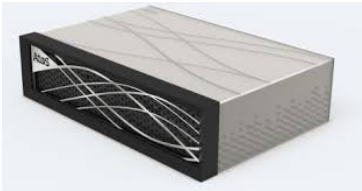
Cloud Service management Multi-Cloud



Mobile "Things" Clouds / Edge Computing



Cloud & Edge computing @ Atos



Atos Bull Sequana Edge Computing Box (prototype)



Atos Codex offerings, is already a significant player in the IoT marketplace.



Other Resources and Materials

► Atos Lookout

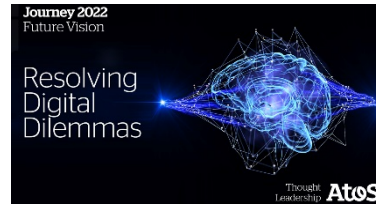
<https://atos.net/content/mini-sites/look-out-2020/>



► Atos Scientific Community

– Journey 2022

<https://atos.net/content/mini-sites/journey-2022/>



– Swarm Computing Whitepaper

<https://atos.net/wp-content/uploads/2018/12/atos-swarm-computing-white-paper.pdf>



Thanks

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