GEORG-AUGUST-UNIVERSITÄT
GÖTTINGEN IN PUBLICA COMMODA SEIT 1737

HPS

Seminar Newest Trends in High-Performance Data Analytics
Supervisor Chirag Mandal

Emerging Trends in Cloud Storage

Johann Eilts

Agenda

Introduction

Cloud Computing Definition[1]

- On-demand access to shared computing resources
  - E.g., networks, storage, service, …

[1] P. Mell, T. Grance, and National Institute of Standards and Technology, “The NIST Definition of Cloud Computing.”

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  - Access through standard mechanisms for thin & thick clients

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- Resource Pool
  - Provider's computing resources are pooled to serve multiple and diverse consumers

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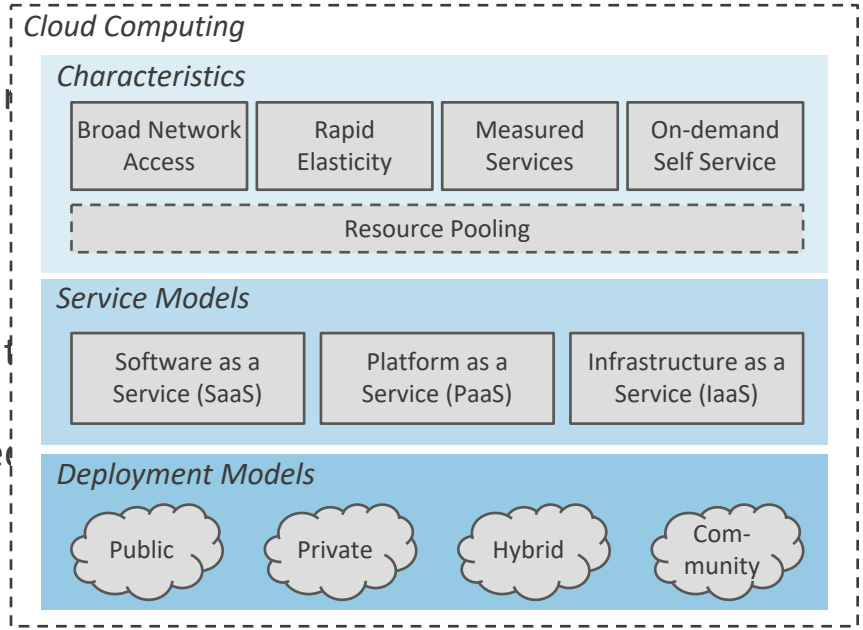

Own illustration based on NIST definition [1]

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Introduction

What is Cloud Storage?[2]

- Remotely store data
- Accessible via the internet
- Data access and management without local storage infrastructure

[2] C. Wang, S. S. M. Chow, Q. Wang, K. Ren, and W. Lou, “Privacy-Preserving Public Auditing for Secure Cloud Storage.”
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Cloud Storage Characteristics[3]

- Architecture depends on use case and user data protection
- Physical & technical storage connections depend on use cases
  - SATA [cost] vs. NVMe [performance]
- Different access protocols
  - APIs (to integrate with applications)
  - File based protocols file transfer independent of applications (FTP, NFS,…)

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Introduction

Why is it important to consider Cloud Storage?[1] [3] [4]

- Reduces “burden” of local data storage
- Major part of cloud computing
- cloud resources can be tailored to use cases
- Worldwide data consumption continues to grow each year

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[4] Statista, “Public Cloud: market data & analysis,”

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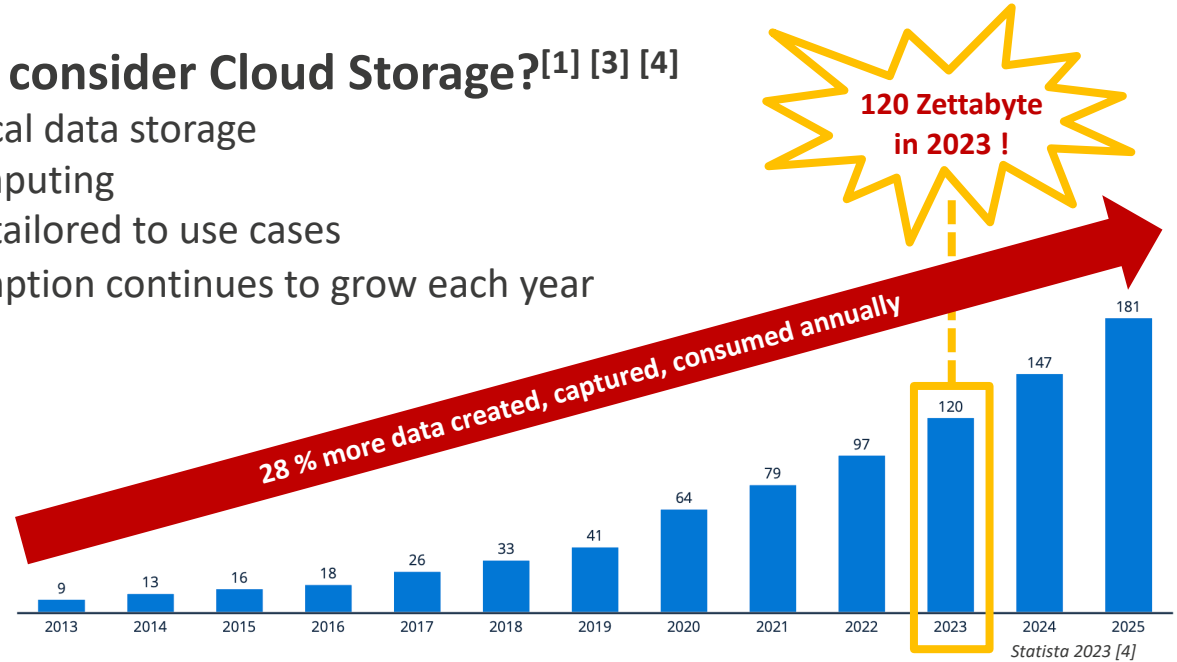
➢ **Storage important**



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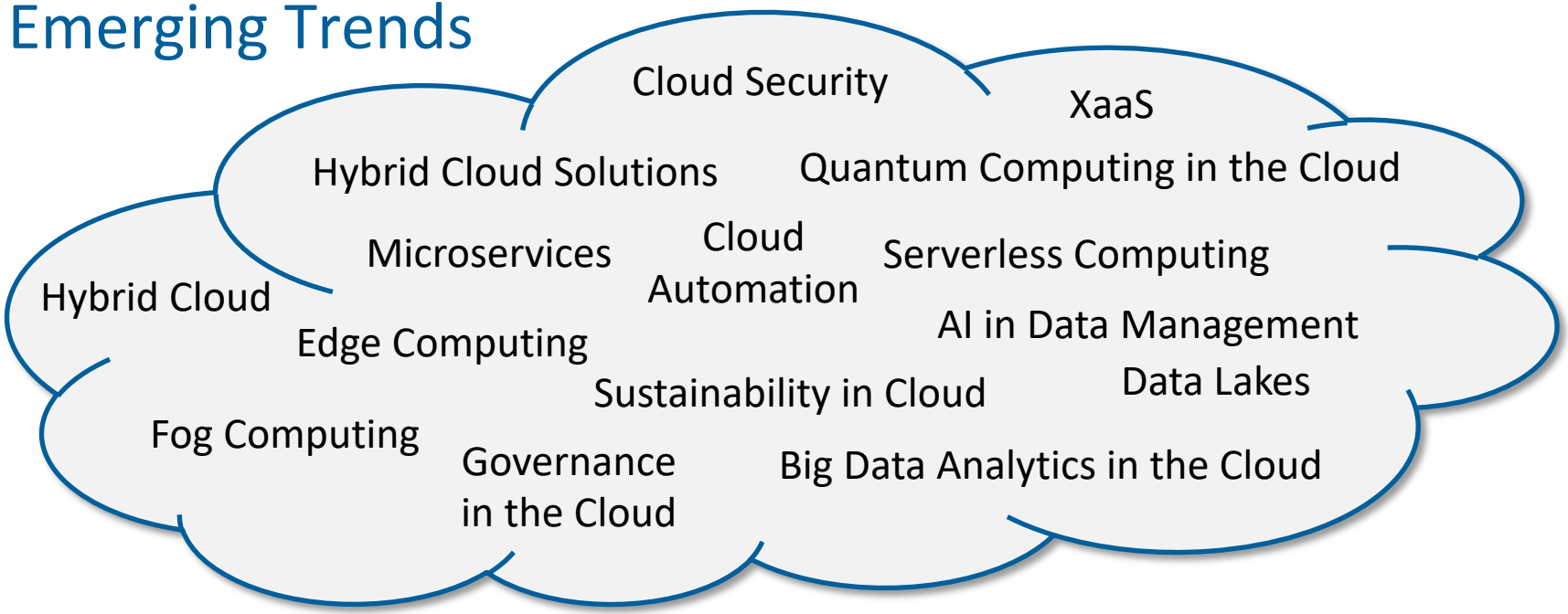
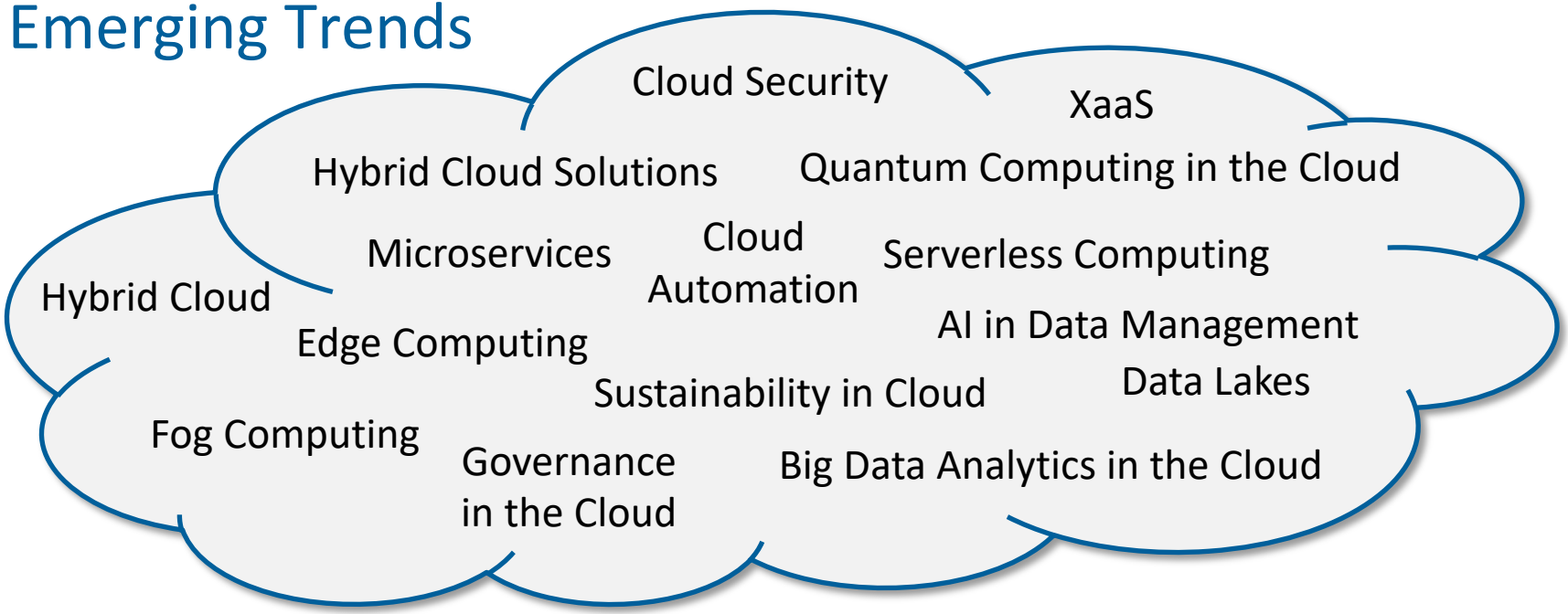
Emerging Trends

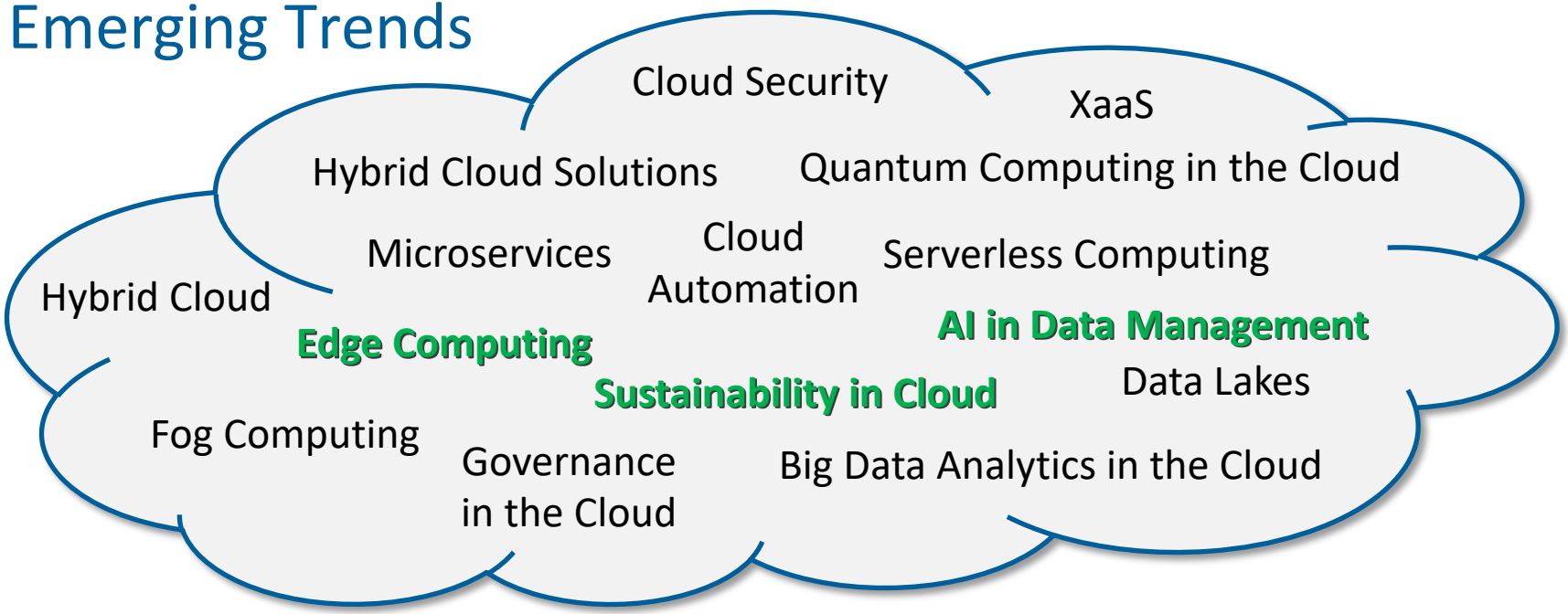


Emerging Trends



What do you think is an important trend in the cloud?

Emerging Trends



Edge Computing

Edge Computing (What?)

Description[5] [6] [7] [8]

- Computing tasks / services are pushed from network core to network edge
- Brings cloud services closer to the edge of the network
  - Where data originates / is generated
  - Reduces network latency of cloud
- Architecture and complimentary approach to cloud computing

[5] IEEE, “Real-Life Use Cases for Edge Computing,”
[6] Z. Zhou, X. Chen, E. Li, L. Zeng, K. Luo, and J. Zhang, “Edge Intelligence: Paving the Last Mile of Artificial Intelligence With Edge Computing,”
[7] M. Simic, I. Prokic, J. Dedeic, G. Sladic, and B. Milosavljevic, “Towards Edge Computing as a Service: Dynamic Formation of the Micro Data-Centers,”
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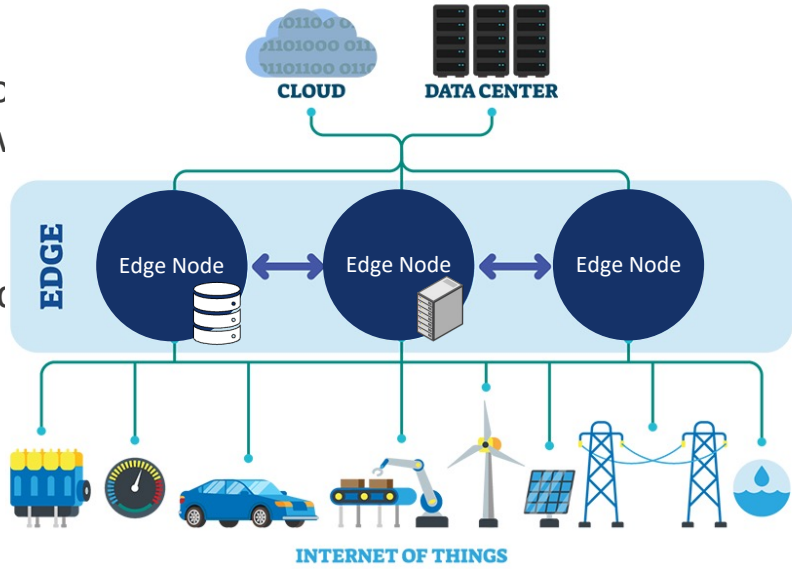

Adapted illustration from IEEE [5]

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Edge Computing (Why?)

Why is it important / an emerging trend?[9] [10]

- Growth of mobile internet traffic
  - Online gaming, UDH streaming
  - Increased speed with 5G
  - Reduction of latency needed
  - High access speed needed

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  - Need for decentraliced storage / caching

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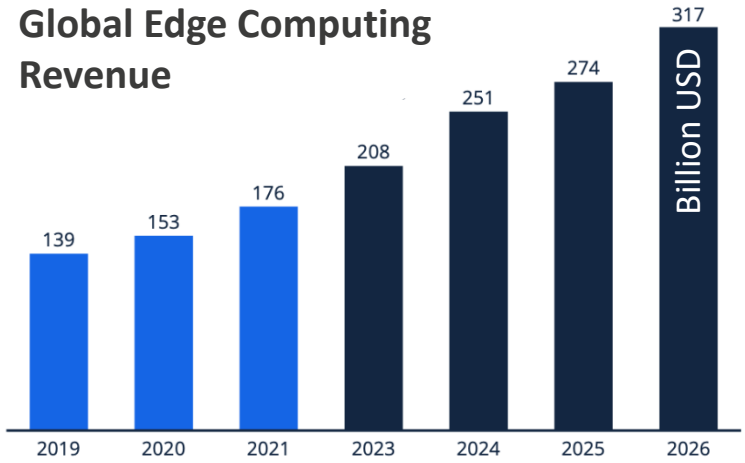

Statista 2023 [9]

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Edge Computing (How?)

How does it work?[11] [12] [13]

- Storage and computing resources are located at the “edge” of the network
  - ➢ Edge nodes; edge computing layer
- IoT devices are data consumers & data producers
- Edge devices request service/content from cloud & perform computing tasks from the cloud
  - ➢ Data storage, caching, processing, delivery service from cloud to user

[11] F. Sepulveda, J. S. Thangraj, and J. Pulliam, “The Edge of Exploration: An Edge Storage and Computing Framework for Ambient Noise Seismic Interferometry Using Internet of Things Based Sensor Networks,”
[12] W. Shi, J. Cao, Q. Zhang, Y. Li, and L. Xu, “Edge Computing: Vision and Challenges,”
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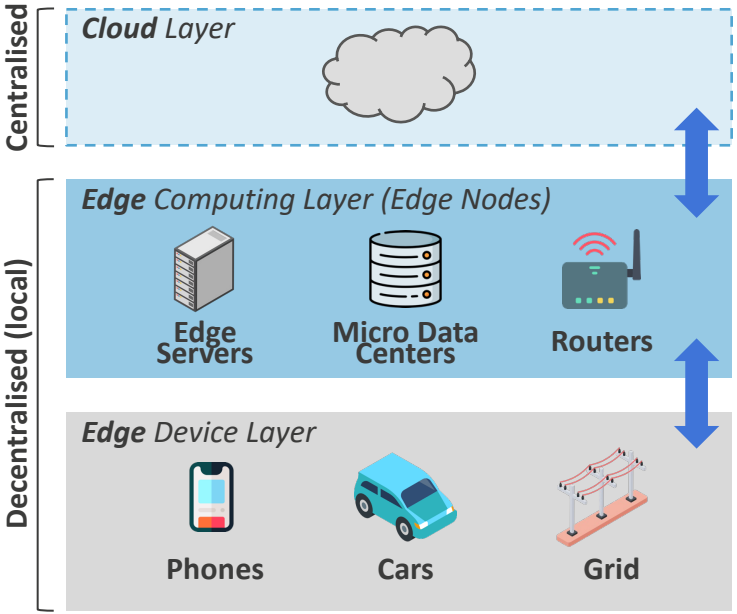

Reference architecture own illustration based on Sepulveda et al. [11]

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Edge Computing Case Study

Content Creation/Consumption/Delivery[14]

Also known as „Mobile edge computing“

- Video streaming as example:
  - Large amount of bandwith needed
  - Esp. Live video streaming like **twitch.tv**

[14] K. Bilal and A. Erbad, “Edge computing for interactive media and video streaming,”

Edge Computing Case Study

Content Creation/Consumption/Delivery[14]

Also known as „Mobile edge computing“

- Video streaming as example:
  - Large amount of bandwith needed
  - Esp. Live video streaming like **twitch.tv**
- Edge devices offer possibility for data processing outside of cloud storage
  - Data only needs to be sent to cloud for storage service
  - transcoding and processing of video data can happen at the edge
  - i.e. edge devices = smartphone

[14] K. Bilal and A. Erbad, “Edge computing for interactive media and video streaming,”

Edge Computing Case Study

Autonomous Vehicles/Driving[15]

- Large amounts of data needed (many sensors)
- Processed with **as little latency as possible** (high speed on the roads)
- Many different technologies come at play
  - ➢ Sensing, decision making, computer vision, …
- Heterogenous systems need to communicate

[15] S. Liu, L. Liu, J. Tang, B. Yu, Y. Wang, and W. Shi, “Edge Computing for Autonomous Driving: Opportunities and Challenges,”

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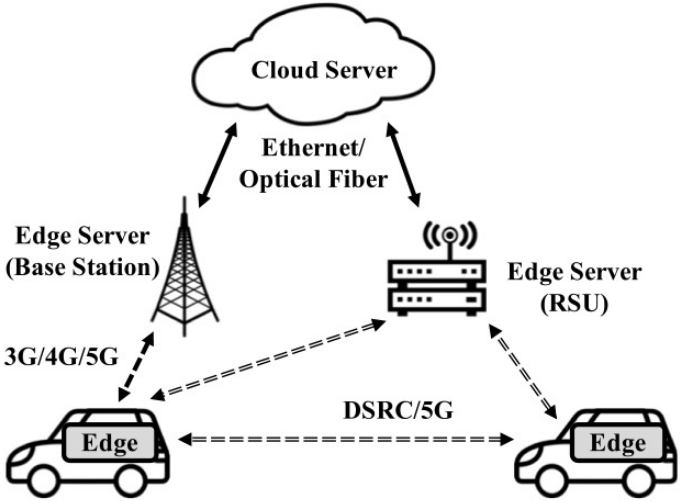

Autonomous driving reference architecture [11]

[15] S. Liu, L. Liu, J. Tang, B. Yu, Y. Wang, and W. Shi, "Edge Computing for Autonomous Driving: Opportunities and Challenges,"

Sustainability in Cloud

Sustainability in Cloud (What?)

Description [16] [17]

- Sustainability in environmental context (in contrast to social, economical…)
- Minimize environmental impact and promote responsible resource use in cloud services
- efficient management of energy consumption, processing, and transport within cloud
- Reducing impact on climate change

[16] J. Baliga, R. W. A. Ayre, K. Hinton, and R. S. Tucker, “Green Cloud Computing: Balancing Energy in Processing, Storage, and Transport,”
[17] K. L. Pendergrass, W. Sampson, T. Walsh, and L. Alagna, “Toward Environmentally Sustainable Digital Preservation,”

Sustainability in Cloud (Why?)

(Real World) Example / Case Study

"As of 2020, **Facebook's** operations are now supported by 100% renewable energy and have reached net zero emissions"[18]

[18] M. Roe and Facebook, "Facebook Reaches 100% Renewable Energy,"
[19] R. Evans and J. Gao, "DeepMind AI Reduces Google Data Centre Cooling Bill by 40%."
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"Value of the green data center market in Europe"[20]
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2030: 49.84 Billion USD (*almost 3.5x as 2023*)

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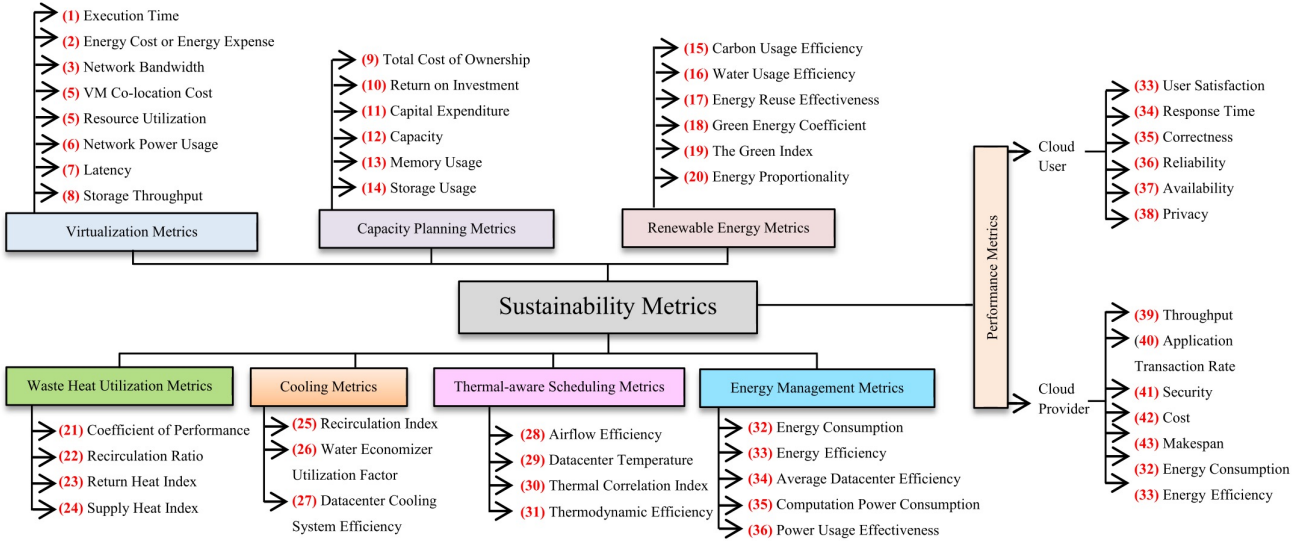


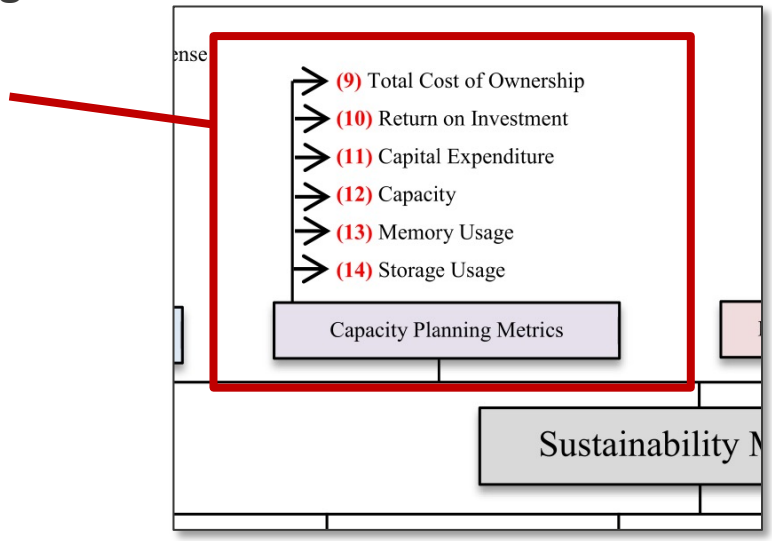
Taxonomy developbed by Gill & Buyya to measure sustainability [21]

[21] S. S. Gill and R. Buyya, "A Taxonomy and Future Directions for Sustainable Cloud Computing: 360 Degree View,"

Sustainability in Cloud (How?)

How can we measure capacity planning?[21]

- Goal: maximize resource usage
- Capacity should be planned for:
  - IT devices (e.g. storage)
  - Power infrastructure
  - Cooling



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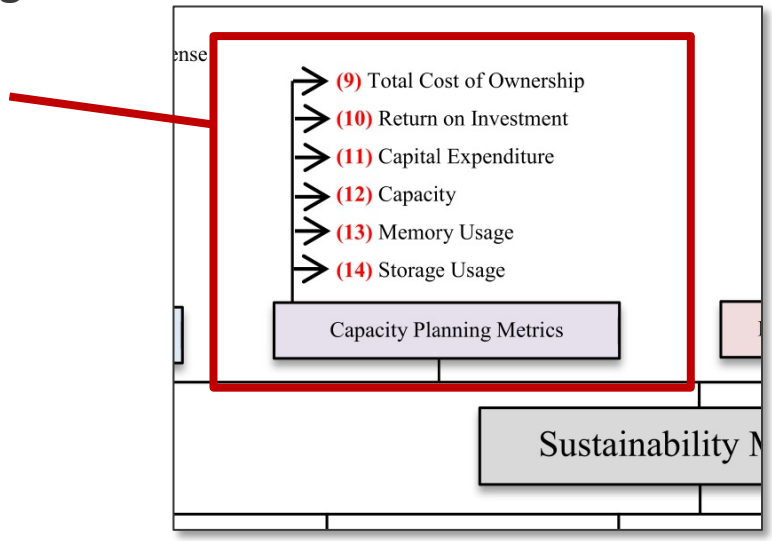
Metric Example [21]

Capital expenditure

"Amount of money used to obtain, upgrade, and maintain physical components related to a cloud data center."



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Consider the (large) number of physical machines (PMs) in data centers:

- Low service downtime cost
- But high Operational costs

➢ Optimal PM capacity requirements need to be determined

[22] R. Ghosh, F. Longo, R. Xia, V. K. Naik, and K. S. Trivedi, "Stochastic Model Driven Capacity Planning for an Infrastructure-as-a-Service Cloud,"

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Ghosh et al. developed an algorithm:[22]

Optimal number of PMs:

Minimizing total cost of ownership (incl. operational costs) with a service level agreement for downtime requirements

➢ Cheaper & less reliable PMs **VS** costlier but more reliable PMs for same service availablity

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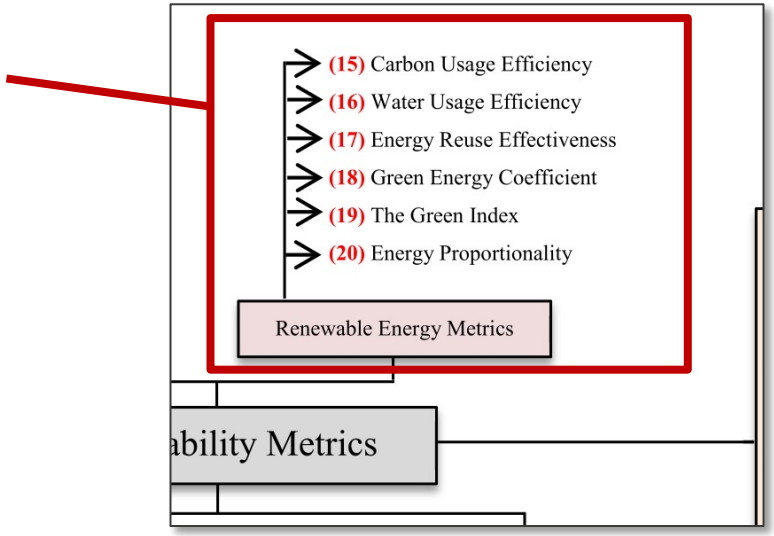
- Public interest in renewable energy
- Reduce energy consumption
- Use of wind/solar/water energy



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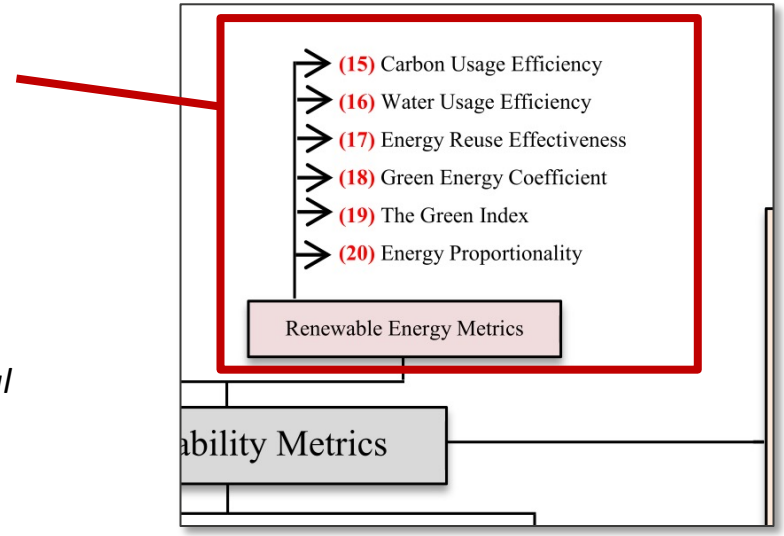
Metric Example [21]

Green Energy Coefficient

"Ratio of green energy consumed by a CDC to total energy consumption of that CDC"



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Sustainability in Cloud (How?)

Green Cloud Strategies Examples[23]

Location of Data Centers

- Microsoft built data centers near dams to harness hydro-power
- Water can also be used for logistics

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Sustainability in Cloud (How?)

Green Cloud Strategies Examples[23]

Location of Data Centers

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Virtualization

- Multiple operating systems on single physical machine
- Fully utilize available resource
- Physical space is reduced by virtual instances
  - Power consumption and cooling also reduced

➢ Virtual machines can also be deployed on edge computing infrastructure

[23] D. S and N. G. Cholli, “Green Cloud Computing: Redefining the future of Cloud Computing.”

AI in Data Management

AI in Data Management (What? Why?)

Description[24]

- ➢ Handling data as a valuable asset to improve decision making
- Data governance
- Architecture
- Security
- Quality
- Metadata management

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[24] tableau, “Data Management: What It Is, Importance, And Challenges.”

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- ➢ Handling data as a valuable asset to improve decision making
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Why?[4]

- ➢ 28 % more data created, captured, consumed annually
- ➢ Influences cloud storage

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AI in Data Management (How?)

Metadata Description[25]

- “Data about data”
- Describes data
- Makes it easier to manage and use data

Name	Age	Gender
…	…	…
…	…	…

[25] J. Park and S. Jeoung, “Raison d’être of the benchmark dataset: A Survey of Current Practices of Benchmark Dataset Sharing Platforms,”
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What is metadata management?[26]

- Data labelling
- Data classification
- Time consuming task when done manually

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AI in Data Management (How?)

How can AI support metadata management?[26] [27]

- AI can extract details from data sources
- Natural language processing can be used for keyword recognition
- Metadata creation can be automated

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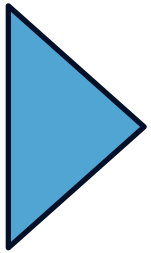
Example [27]

AI can transcribe speech in video data, then tag it with metadata.



Increases data quality [28]

Inconsistencies can be automatically detected if wrongly assigned to metadata

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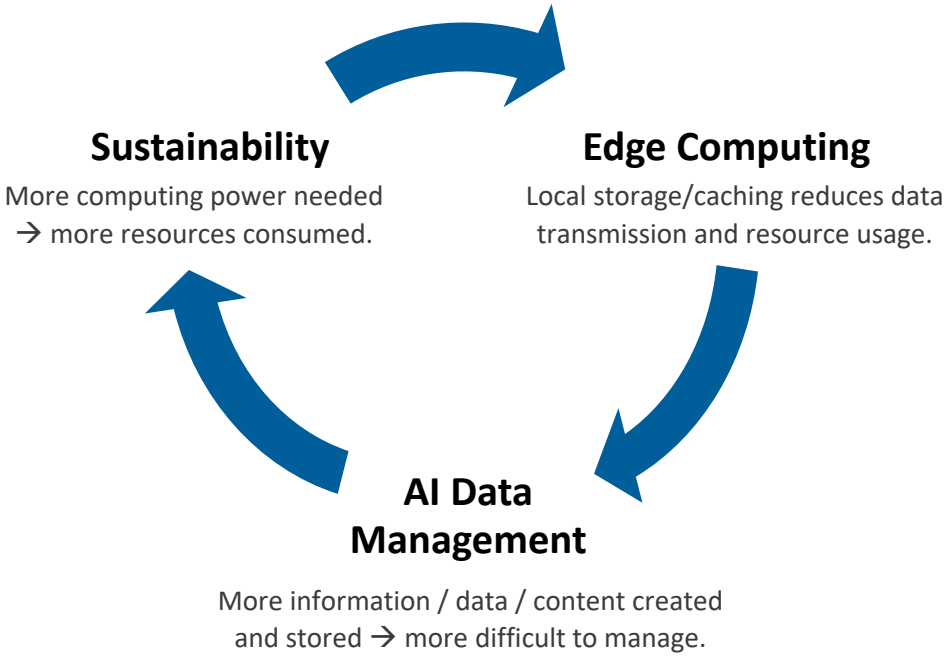
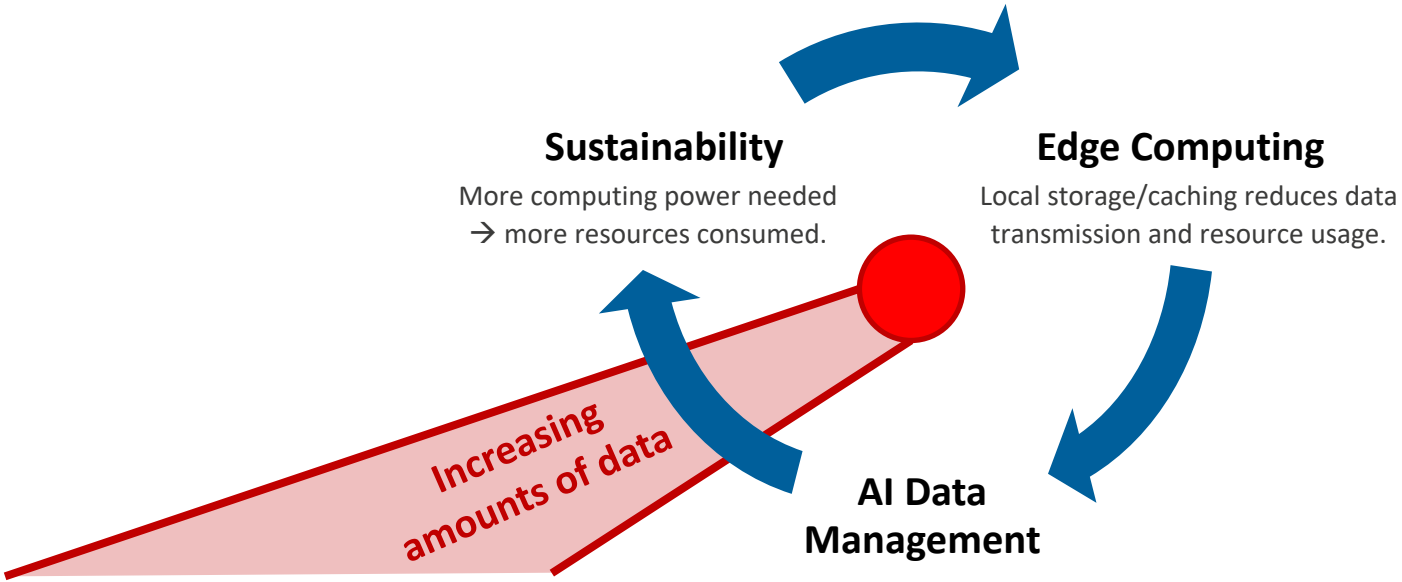

Sustainability
More computing power needed → more resources consumed.
Edge Computing
Local storage/caching reduces data transmission and resource usage.
AI Data Management
More information / data / content created and stored → more difficult to manage.

Conclusion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Increasing amounts of data

Discussion

- POV influences importance of a trend (government vs. business vs. science)
- Companies with goals/agendas can push certain trends
  - Same goes for regulations/governments
- Some emerging trends might not have any impact at all (e.g. personal clouds, 3D TV, …)
- Also consider societal impact of trends (e.g., negative impact of social media)
- Maturity of trends to be adopted may take time (maybe something new gets established before)
  - E.g., HD DVD / Blu-Ray vs streaming
- New industries might emerge from trends
  - E.g., large scale cloud adoption → cloud security solution industry

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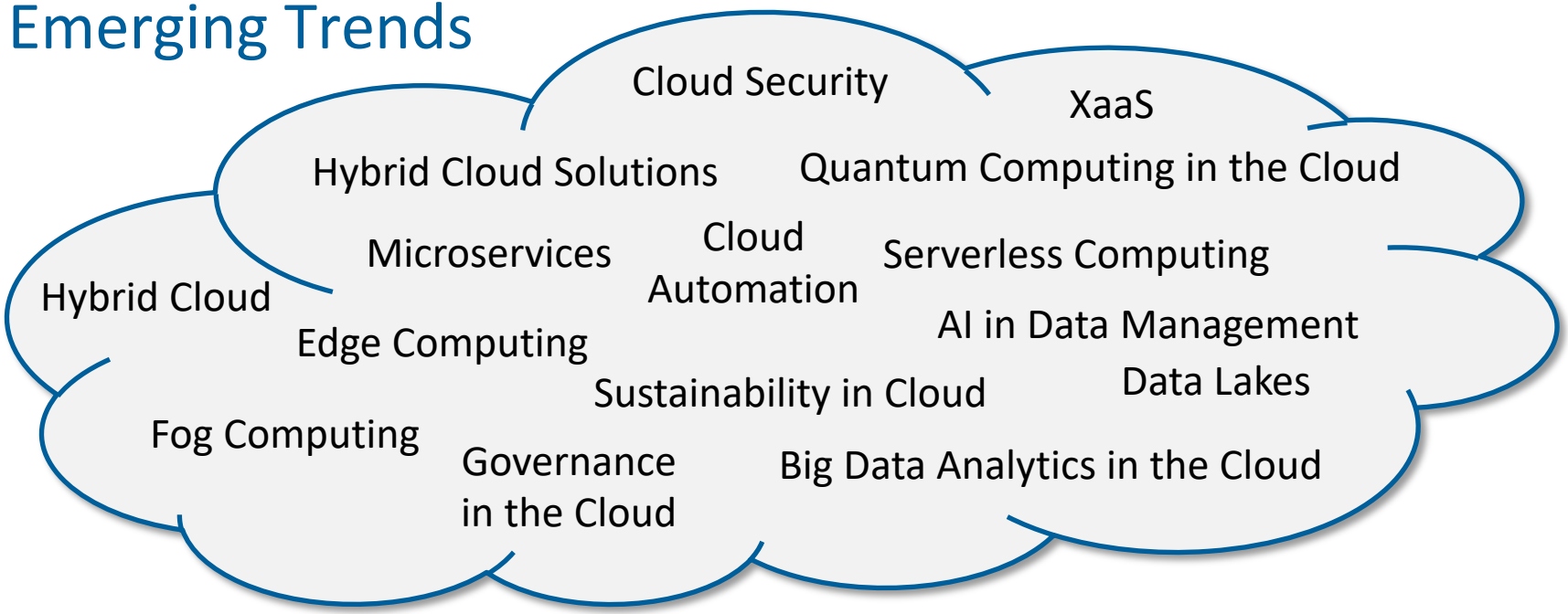
Emerging Trends



What do you think is an important trend in the cloud?