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Research on Cloud Computing Technology Graph Analysis

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***Abstract*—As a hot research field this year, cloud computing involves various technical fields. From the perspective of the research subject, how to effectively analyze the development trend of cloud computing technology and how to formulate a cloud computing evolution route that suits itself has become an urgent problem to be solved. Based on the classification of cloud computing products of mainstream cloud providers and consulting organizations in the industry, this paper introduces a method of splitting the underlying technology of cloud products, conducting product-technology two-dimensional analysis of different technologies, and providing technical research and development suggestions from the fields of cloud infrastructure, cloud services, cloud operations and governance, and cloud security.**

Keywords- cloud computing; product-technical matrix; technical analysis

I. INTRODUCTION

In the past ten years, cloud computing has experienced a blowout development. Many cloud vendors continue to invest in their own research and development, hoping to occupy a place in the field of cloud computing. Compared with localized deployment, cloud computing has the advantages of flexible resource invocation, decoupling of business resources, and optimization of construction costs. However, due to the huge market in the field of cloud computing, while paying attention to the development of cloud computing technology, it should actively embrace mature cloud ecological resources. Through detailed technical analysis, it will have a positive impact on the ecological participation and ecological construction of cloud merchants.

On the one hand, mainstream cloud providers in the industry, such as AWS and Alibaba Cloud, combined their own cloud computing characteristics to release knowledge/technology graphs for the analysis and application of cloud computing technologies. Through the construction of a knowledge center, AWS[1] provides a panoramic technical service knowledge graph on the AWS cloud, including 17 categories and 111 technical service directions, and provides AWS ecological construction guidance for third-party cloud providers. Alibaba Cloud[2] Developer Center provides Alibaba Cloud technology graph, including 23 categories and 208 technical points. Unlike AWS, Alibaba Cloud is more inclined to guide users and developers to conduct R&D on Alibaba Cloud and provide a corresponding R&D environment.

On the other hand, well-known consulting organizations are also focusing on the development trend of cloud computing technology, and provide reference technology development analysis reports to the industry. Gartner focuses on the field of cloud computing. From 2020 to 2022, Gartner will update the cloud computing technology maturity curve every year[3][4][5]. In 2021, it released the cloud security technology maturity curve[6]. In the emerging technology curve announced in 2022[5], the industry cloud platform is also a key technology direction. In 2022, IDC released the top ten forecasts of China's cloud computing market[7], analyzing the evolution trend of emerging cloud technologies from the perspective of market-product demand. At the same time, IDC focuses on industry cloud-related content, and makes analysis and forecasts on the development of industry cloud technologies such as video cloud and medical cloud.

In addition to cloud business and consulting institutions, scientific research institutions have also discussed the cloud computing map from different perspectives. According to the scene-based content association of the cloud service market, Zhang[11] built a knowledge graph to help customers order cloud services in related business scenarios. Huang[12] used the project requirements template to match the cloud service knowledge graph with the template requirements and feature sets, and recommends better project construction solutions to customers. Amrita Saha[13] organized the knowledge graph based on AIOps-related content in specific scenarios to locate problems in the Ops and standardize the overall AIOps process with certain technologies. Yang[14] mainly focuses on the application of multi-cloud in IoT scenarios,

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and builds a knowledge graph around the occurrence and solutions of defects in the production process.

This paper aims to establish a cloud computing technology analysis method that can effectively analyze technology development trends and put forward research and development suggestions. The current technical graph or knowledge center of mainstream cloud providers is biased towards internal technical training and technological ecological evolution. Research on technology maturity and market technology trends by consulting agencies is more focused on trend recommendations for emerging hot technologies, and less involved in the overall view of technology. The design graph of scientific research organizations is mostly based on scenario-based solutions, such as the cloud market, IoT, and AIOps, which has obvious industrialization or purpose. At the same time, the knowledge map is biased towards component database storage and lacks the hierarchical relationship of the cloud computing system. Therefore, there is an urgent need to design a set of technology graph methods that can conduct technology research and development analysis based on the organization's own needs under the overall view dimension of cloud computing.

II. PROPOSED CLOUD TECHNICAL GRAPH

A. Technology multi-dimensional division

The cloud computing technology graph framework is shown in Figure 1, which is divided into five technical dimensions: cloud infrastructure[9], cloud service, cloud operation and governance, cloud security, and cloud solutions. Cloud infrastructure focuses on technical content such as basic hardware, basic software, and cloud platform in the process of cloud construction. Cloud services include IaaS services, such as elastic computing, elastic storage, elastic network, etc., PaaS services[10], such as databases, middleware, big data, etc., security services and APaaS services. Cloud operation and governance provides corresponding technical analysis from the perspectives of cloud operation and cloud governance. Cloud security mainly describes the full-stack security protection of cloud computing, from the underlying infrastructure to the top-level cloud security governance. Cloud solutions cover industry cloud, hybrid cloud, edge cloud, etc., providing a full set of technical solution output.

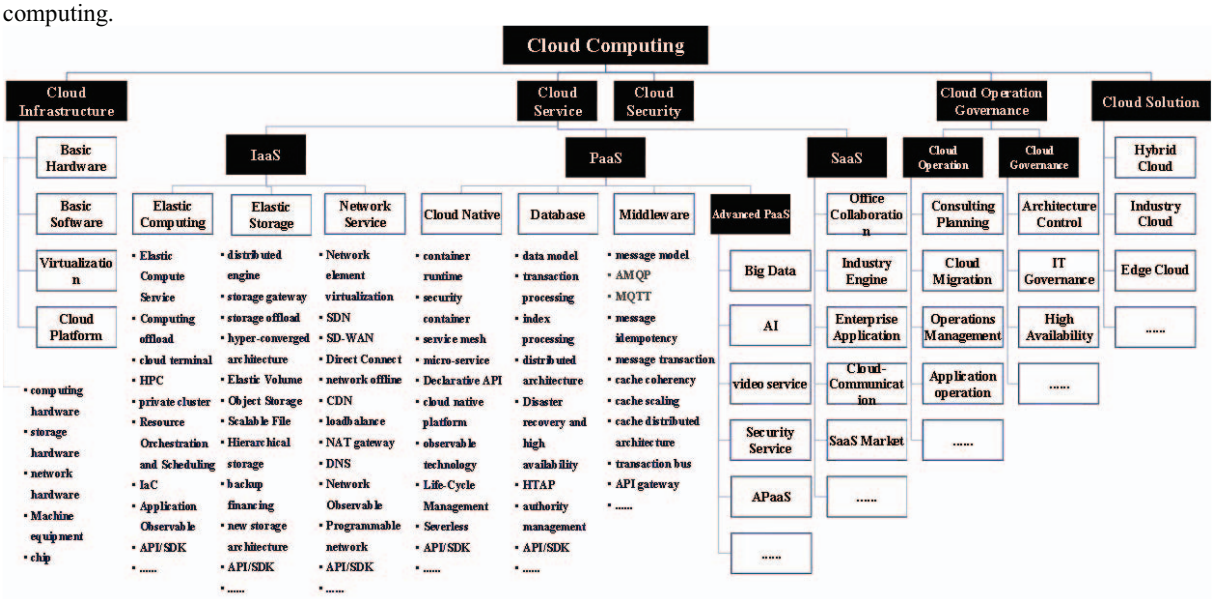

Figure 1. Cloud Computing Technology Graph Framework

1) Cloud Infrastructure Sub-Graph Design

a) Chip. The chip is the core component that is difficult to bypass in cloud computing. Research and design will be carried out from the design architecture, instruction set, high-speed interconnection, and packaging technology.

b) Machine Equipment. The design content of machine equipment is oriented to server customization technology, storage device research and development technology, network equipment customization and hardware offloading technology, and security device technology.

c) Basic Software. The basic software focuses on the underlying computing, scheduling, and operation and maintenance software of cloud computing, focusing on cloud operating systems, firmware software, operation and maintenance monitoring, and pooling software, as well as middleware, databases, and devops software.

d) Virtualization. As an important part of cloud computing, virtualization focuses on computing virtualization, network virtualization, and storage virtualization. Combined with the rise of cloud native, the content of operating system virtualization is proposed around containers and WASM.

e) Cloud Platform. The cloud management platform undertakes cloud resource deployment and scheduling tasks, including technologies related to computing resources, network resources, and storage resource cloud management. At the same time, it analyzes resource

scheduling and orchestration technologies. Combined with cloud native technology and the evolution trend of cloud management technology in the industry, research and design are carried out on distributed cloud and new generation cloud management framework.

2) Cloud Service Sub-Graph Design

a) Elastic Computing. Cloud providers provide computing services to customers, including mainstream product technologies such as elastic compute service and cloud terminals. Combined with the evolution trend of high availability and high performance of cloud computing, dismantling and analysis of HPC, elastic orchestration technology, intelligent computing power technology, etc.

b) Elastic Storage. Elastic storage includes the underlying distributed engine, and the upper layer includes product technologies such as block storage, file storage, object storage, and storage gateways. In addition, graph focuses on storage backup migration, storage acceleration offloading, hierarchical storage, storage intelligent management, data protection service and other tech-content.

c) Network and CDN. Network services provide customers with access to the cloud network, intra-cloud network, inter-cloud network, and wide area network. It is necessary to research and design basic network technologies including Elastic-IP, VPC, SLB, and NAT, as well as applications service technology such as SDN, SD-WAN, network observability, and Cloud Direct Connect. CDN services include CDN and edge computing products and services, designed from CDN acceleration technology, security acceleration technology, PCDN to cloud-edge collaboration technology, using edge node acceleration technology to promote the evolution of cloud rendering, cloud gaming and other service technologies.

d) Containers and Middleware. Container services include a variety of container runtime technologies, container orchestration management technologies, service grid technologies, and cloud-native deployment and delivery technologies provided to users. In addition to general-purpose technologies, emerging technologies such as edge lightweight container technology and serverless are also the focus of graph. Middleware services include message middleware, microservice management, operation and maintenance monitoring, etc., focusing on mainstream message queue cloudification technology, event-driven architecture technology, service gateway, cloud native monitoring technology, etc.

e) Database. The database is designed around relational databases, NoSQL, data warehouses and database tools, including common SQL analysis technology, data model management technology, execution optimization technology, data storage technology, distributed architecture and disaster recovery technology, etc. It also includes database cloud technology, HTAP integration technology, etc.

f) Video Service. Video services can be split into basic video processing technology and AI+ video technology. Basic video processing technology, including audio and video transcoding, encryption and digital watermarking, audio and video enhancement, etc. AI+ video technology includes audio and video intelligent analysis technology, intelligent review technology, intelligent synthesis technology, etc., and analyzes media management and media storage technology.

g) AI. The AI service sub-graph is specifically designed with AI basic platform construction, AI model algorithm, AI capability opening, and AI security service. Basic platform technologies include AI training framework adaptation technology, AI software and hardware acceleration adaptation technology, AI heterogeneous computing power adaptation technology, etc. AI model algorithms include machine learning, reinforcement learning, NLP, ASR/TTS, style transfer, XR, human-computer interaction, etc. AI capability opening includes open interface adaptation, intelligent low-code platform, intelligent service and other technologies. AI security can provide service technologies such as privacy computing.

h) Big Data. The Big Data service sub-graph design includes technical dimensions such as data access, data storage, data processing, data application, basic platform construction, data capability opening, and data security services.

i) Cloud Security Services. Cloud security service technology map, focusing on the analysis of technical content such as network security architecture, data service security, computing power security that customers can order, and technical dismantling of SaaS application security technology and service security management technology

3) Cloud Operation and Governance Sub-Graph Design

a) Cloud Operation. The cloud operation technology graph includes six technical dimensions, namely consulting planning, migration deployment, operation management, application operation, security operation, and ecological operation. Consulting planning disassembles technologies such as service life cycle analysis, demand analysis and design, and basic environmental assessment. Migration deployment includes migration technology across cloud data, containers, and images. Operation management conducts technical analysis around AIOps and operational efficiency tools. Application operation and security operation focus on the operation strategy technology and operation platform support technology in the corresponding field. Ecological operations provide cooperative training systems, partner certification systems and other full-process evaluation technologies.

b) Cloud Governance. The cloud governance technology graph includes five technology categories, namely identity authority governance, data security governance, general security governance, business continuity governance, and cost governance. Identity authority governance technology revolves around identity authority identification audit design. Data security governance technology includes the whole process of

collecting, transmitting, storing, processing, exchanging, and destroying data. General security governance focuses on the technical content of network security, application security, and host security governance other than data. Business continuity mainly focuses on cloud service availability governance, and cost governance design includes budget, resource usage, and cost deviation.

4) Cloud Security Sub-Graph Design

a) Cloud Infrastructure Security. Cloud infrastructure security technology describes the security of the underlying hardware support of cloud computing, including the security of the underlying physical environment of the cloud, the security of the underlying cloud equipment, and the security of virtualization, etc.

b) Cloud Data Security. Cloud data security technology describes cloud service process data security protection content, including cloud information content security, cloud password information security, big data service security, etc.

c) Cloud Network Security. Cloud network security technology describes cloud computing networking and network service security content. Network security includes network device terminal security, network communication security, etc. Cloud service security includes elastic network security, zero trust, network access detection, cloud network threat detection and protection, etc.

d) Cloud Application Security. Cloud application security describes the cloud computing devops process and application security content, from component security, code security, to API security, APP security, and finally includes the overall supply chain security protection.

e) Cloud System Security. Cloud system security describes the security content of cloud computing support components, including cloud host security, container security, mirror protection, database and middleware security protection.

5) Cloud Solutions Sub-Graph Design

a) Industry Cloud. Industry cloud solutions, including general component aggregation technology in different industries, further forming an APaaS technical solution delivery system, the bottom layer relies on low-code technology for design.

b) Hybrid Cloud. Hybrid cloud solution, providing public and private cloud management technology, multi-cloud resource hybrid scheduling and orchestration technology. Based on the general technology of private cloud and public cloud, hybrid cloud needs to have all-in-one service technology.

c) Edge Cloud. Edge cloud solutions can be divided into various application scenarios. Cloud service scenarios, including lightweight platform architecture technology, computing sinking, edge-end video rendering technology, cloud gaming technology, etc. In the 5G scenario, add the bearer technology for network edge network elements. At the same time, the edge cloud has edge device collaboration technology, including lightweight edge all-in-one machine technology, edge box and other characteristic technologies

B. Proposed Cloud Product View

In order better guide the cloud technology map to serve technology research and development, not just as a knowledge system, it is necessary to build a complete cloud product view in line with the industry ecology, as an important reference content for technology research and development suggestions. For each technical dimension in Section A, AWS, Azure, Alibaba Cloud, Huawei Cloud, and Tianyi Cloud are analyzed in a unified manner, and a four-level product tree form is designed. Figure 2 shows a product tree structure of Database.

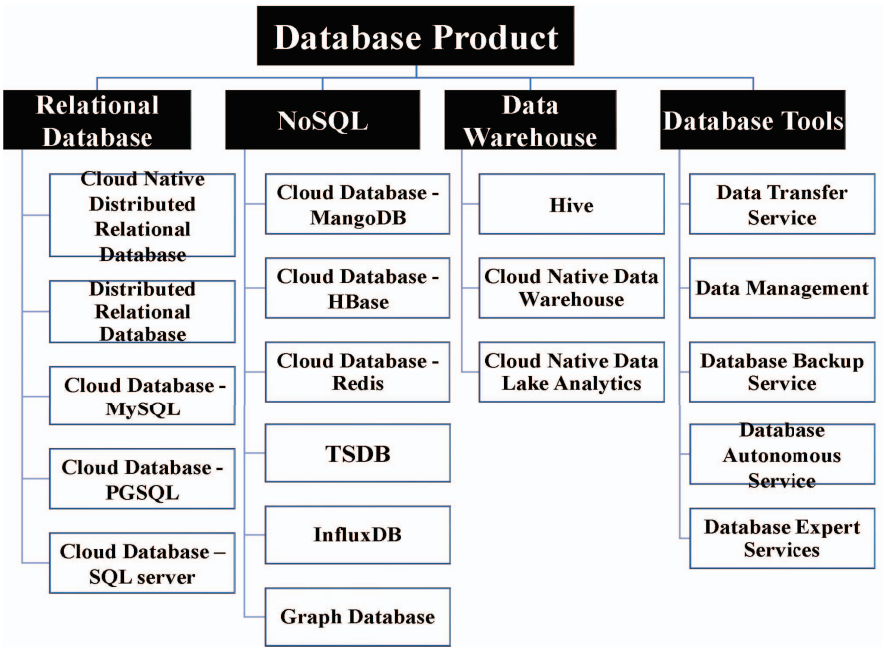

Figure 2. Database Product Analysis Structure

The leaf node of the product tree, researching and summarizing the mainstream products of cloud providers in the industry, and adding key breakthrough service products according to the technological development trend of the industry. Taking database services as an example, the design process integrates mainstream cloud database products of cloud providers, such as cloud-native databases and database tools, as well as graph databases and data warehouses whose technologies in cloud services still need to be improved. Designing a complete and usable product view can lay a solid foundation for subsequent product-technology matrix analysis.

C. Technology Maturity and Technology Importance

1) Technology Maturity. Combined with Gartner's hype cycle and emerging cloud technology predictions[5], a technical expert group evaluates the technology maturity[8]. The specific evaluation principles are shown in Table I.

TABLE I. TECHNOLOGY MATURITY EVALUATION PRINCIPLE

Maturity Level	Discrimination Mark	R & D Strategy	Benefit Effect
Technology Trigger	Germination of con-cept or theory.	Concept tracki ng & pre-rese arch	Concept interpretation
Peak of Inflated Expectations	Widely concerned by the industry, pres enting a certain tech nical bubble.	Technology pre-research	Hotspot tracking and verification
Trough of Disillusionment	Technical cognitio -n returns to ration ali-ty, and the bub ble bursts.	Technology pr oto-type devel opment	Technology acc u-mulation and t rial and error
Slope of Enlightenment	The scope of appli -cation of the tech nology is clear and specific, and there is a broader under standing	Technology de vel-opment	Achieve industr y advantages thr ough first-move r accumulation
Plateau of Productivity	Proven and recog-nized technical be-nefits	Technology an d p-roduct dev elopment	Benchmark the i ndustry's leadin g level and impr ove product indi cators

2) Technology Importance. Combined with the company's technology development route and business focus, the technical expert group evaluates the technical importance of the technology. The specific pricing principles are shown in Table II.

TABLE II. TECHNOLOGY IMPORTANCE EVALUATION PRINCIPLE

Importance Level	Discrimination Mark	R & D Strategy	Benefit Effect
Core technology	Possess industry-lea ding advantages and R&D has important value	Independent dev elopment	Build competiti veness and indu stry barriers
Key technology	Indispensable techno logy on the critical p ath of product develo pment	Mainly indepen dent developme nt	Improve technic al route control
Common technology	Multiple Technolog y Alternative Paths	Independent dev elopment or coo perative develop ment or procure ment	Cost-benefit co nsiderations
General technique	Mature technologie s that are not key te chnology routes of enterprises	Mainly cooperat ive development or procurement	Cost-benefit co nsiderations

III. CLOUD TECHNICAL GRAPH MATRIX ANALYSIS

A. Product-Technology Matrix Design

In detail above, the current technical system of cloud computing has been described. At the same time, the establishment of the product system of mainstream cloud providers has been clearly explained in the form of examples. This chapter will combine the two systems, and it is necessary to find the relationship between them in order to give feasible suggestions for the development and research of cloud computing technology.

In the process of system matrix design, four technical research and development requirements need to be considered to ensure that technical analysis has landing value. The four R&D requirements are:

- R&D direction assessment. Focus on the hot industry track and emerging trend track of cloud computing, and formulate targeted R&D routes.
- New technology mining. Predict the creative technologies of various technical routes of cloud computing, and plan R&D strategies on the premise.
- Core technology control. Pay attention to the R&D obstacles of cloud computing technology route, determine the core technology, and invest a lot of R&D force to tackle key problems。
- Repeated research and development of similar technologies. Sort out the R&D status of similar products from different teams within the enterprise, coordinate resource costs, and achieve a horse racing mechanism within the enterprise.

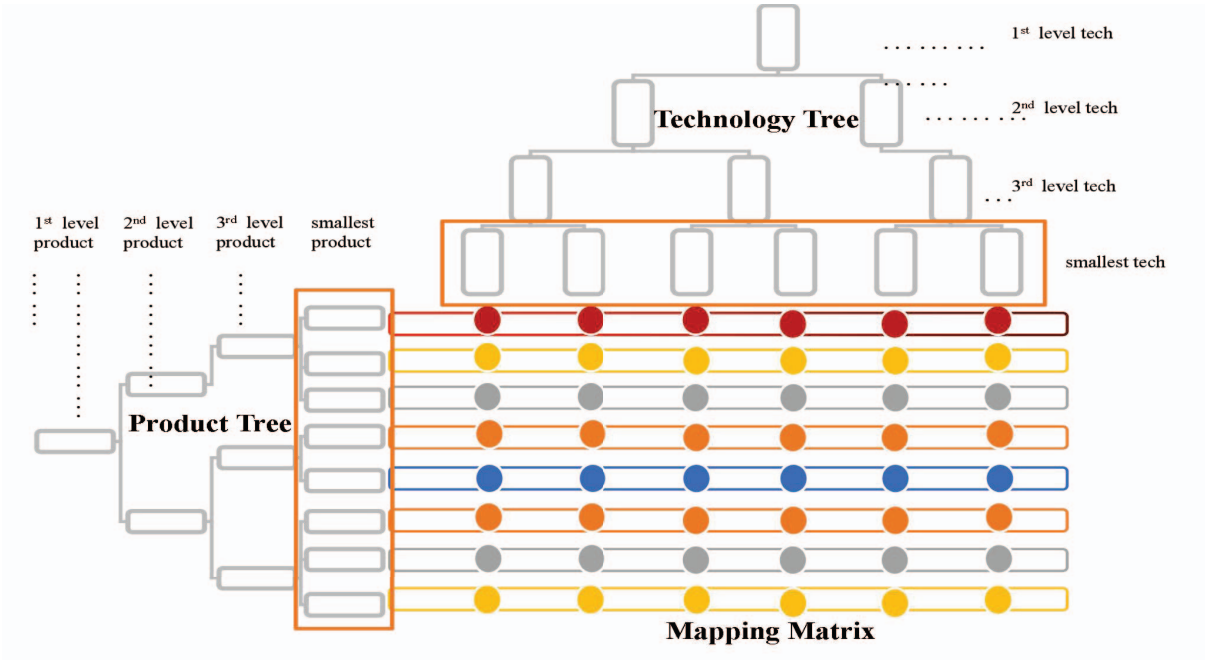

Figure 3. Mapping Matrix Model of the Product Tree and Technology Tree

Focusing on the above four application requirements, the design splits the product into the smallest technology unit that can be developed and researched, and forms the mapping matrix of the product tree and technology tree. The mapping matrix model is shown in Figure 3.

The matrix design combines the technology maturity to analyze the development trend of different technologies, which is effectively used for new technology mining. Based on the development needs and priorities of enterprise cloud computing, analyze different minimum technical units, sort out whether the technology should be controlled independently, or need to seek ecological cooperation to achieve core technology control. Through the reference analysis of the product tree and technology tree, the R&D direction assessment and R&D suggestions are given in the mapping matrix. At the same time, technical suggestions for similar products can also effectively reduce repeated-R&D. Figure 4 shows the matrix analysis results of elastic storage.

Technology Importance				Core Tech	Core Tech	Core Tech	Core Tech	Key Tech	Key Tech	Key Tech	Core Tech	Common Tech	Common Tech	Key Tech	Common Tech
Technology Maturity				POP	POP	POP	SOE	SOE	SOE	SOE	PIE	PIE	POP	POP	POP
Tech / Tree / Pro Tree			1st level	Cloud Service											
			2nd level	IAAS											
			3rd level	Storage											
1st level	2nd level	3rd level	4th level	Distributed Storage Engine	Storage Gateway	Storage Virtualization	SmartDedupe & SmartCompression	Data Disaster Recovery	Data Prctection	Hierarchical Storage	Storage Offload Acceleration	New Type Storage	Storage API/SDK	Data Migration	Blu-ray Disc
Cloud Service	Elastic Storage	Basic Storage Service	Elastic Volume	Self-R&D	Self-R&D	Self-R&D	Self-R&D	/	Self-R&D	/	Self-R&D	/	Self-R&D	/	/
			Object Storage	Self-R&D	Self-R&D	Self-R&D	Self-R&D	/	Self-R&D	Self-R&D	/	Cooperative-R&D	Self-R&D	/	/
			Scalable File - NAS	Self-R&D	Self-R&D	Self-R&D	Self-R&D	/	Self-R&D	Self-R&D	/	/	Self-R&D	/	/
			Scalable File	Self-R&D	Self-R&D	Self-R&D	Self-R&D	/	Self-R&D	/	Self-R&D	Cooperative-R&D	Self-R&D	/	/
			Scalable File -HDFS	Self-R&D	Self-R&D	Self-R&D	/	/	Self-R&D	/	/	/	Self-R&D	/	/
			Scalable File - Database	Self-R&D	Self-R&D	Self-R&D	/	/	Self-R&D	/	/	/	Self-R&D	/	/
			Archiving Service	Self-R&D	Self-R&D	Self-R&D	/	/	Self-R&D	Self-R&D	/	/	Self-R&D	/	Procurement or Ecological Introduction
			capacity Unit Pack	Self-R&D	/	Self-R&D	/	/	/	/	/	/	Self-R&D	/	/
		Data Migration	Data Migration Service	Self-R&D	Self-R&D	/	/	Self-R&D	/	/	/	/	Self-R&D	Self-R&D	/
		Data Storage Service	Log Service	Self-R&D	Self-R&D	/	Self-R&D	/	Self-R&D	/	/	/	Self-R&D	/	/
			Cloud Backup Service	Self-R&D	Self-R&D	Self-R&D	Self-R&D	/	Self-R&D	Self-R&D	/	/	Self-R&D	Self-R&D	/
			Intelligent Media Management	Self-R&D	Self-R&D	Self-R&D	Self-R&D	/	Self-R&D	Self-R&D	/	/	Self-R&D	/	/
			Network Disk Service	Self-R&D	Self-R&D	Self-R&D	Self-R&D	/	Self-R&D	Self-R&D	/	/	Self-R&D	/	/
		Storage Gateway	Cloud Storage Gateway	/	Self-R&D	/	/	/	/	/	/	/	Self-R&D	/	/

Figure 4. The Matrix Analysis Results of Elastic Storage

B. *Matrix application example*

1) R&D Analysis of Similar Products of Elastic Storage. There are four elastic storage-related products within the enterprise, and the development paths overlap to varying degrees. Therefore, it is necessary to split the products and sort out the underlying technologies to avoid unnecessary repeated development.

Combined with the mapping matrix, different levels of elastic storage technologies are mappe. And corresponding

to the technical units of different products, it can be clearly seen that storage virtualization and distributed storage engine are public basic components. Enterprises should have unified R&D standards, upper-level storage services form a horse racing relationship, and optimize their respective application scenarios. The specific analysis process is shown in Figure 5.

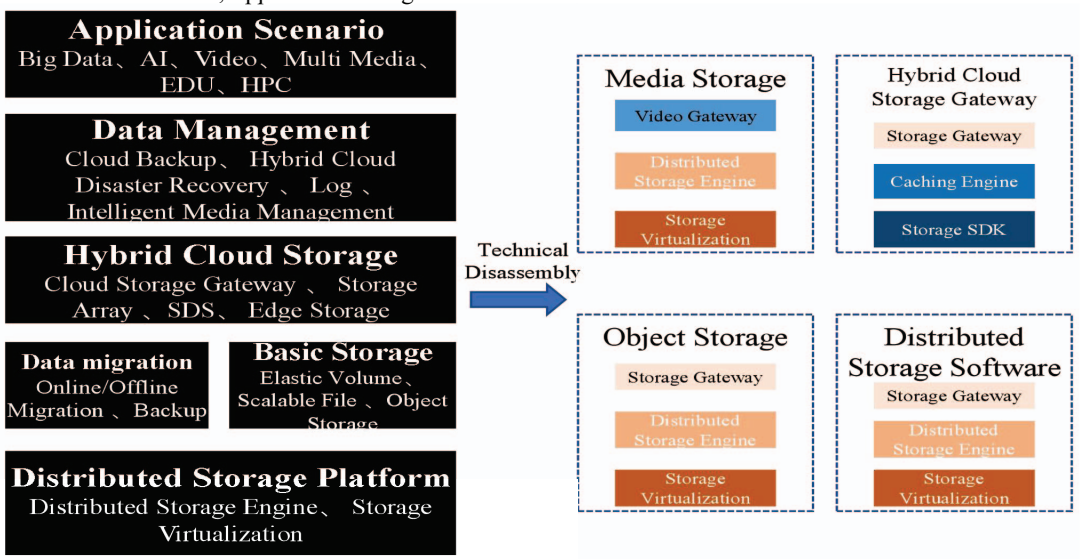

Figure 5. Storage Products Technical Disassembly

2) RISC-V R&D Proposal Analysis. The product tree shows that products such as edge heterogeneous processors, cloud-network customized acceleration processors, and high-performance general-computing integrated processors have great research value. Split the technical units of multiple products, among which the RISC-V instruction set is open and free, which has great advantages in modular R&D and expansion. At the same time, the RISC-V ecological scale is still growing vigorously and has strong research value. It is actively recommended that enterprises invest sufficient strength in the R&D process.

IV. CONCLUSION

The article introduces the content of cloud technology in detail, and how to use the product-technology mapping matrix to analyze cloud computing technology and give R&D suggestions. The cloud computing full-stack technology is subdivided into five dimensions: cloud infrastructure, cloud services, cloud operation governance, cloud security, and cloud solutions. In each dimension, design a sub-graph of different technology classifications, and split the underlying technology of the service technology products under the sub-graph. Refer to the indicators and algorithms of technical analysis in the industry, apply them to the analysis of underlying technical units, and comprehensively form R&D suggestions for this technology in products.

In the process of matrix analysis, integrating the development trend of cloud technology and enterprise technology strategy can effectively solve the pain points in the process of enterprise cloud technology development. First of all, the splitting of the product tree provides suggestions for the company's next technical direction assessment, and the company can quickly follow the industry's development direction and gradually become the leader of the corresponding track. Secondly, analyze the maturity of the underlying technology, and formulate corresponding R&D strategies for technologies with different maturity levels, so as to facilitate the mining of new technologies. Thirdly, analyzing the importance of technology can effectively clarify the core and key content of enterprise cloud computing development, and concentrate on overcoming core technical barriers. Finally, product technology decomposition helps to avoid unnecessary repeated research and development within the enterprise and optimize R&D content.

Of course, there are still certain problems in the graph. The product decomposition is highly professional and the technical points are complex. The update and maintenance of the graph are also problems that need to be overcome. In the future, we will gradually explore effective digital management mechanisms and organize technical expert groups to coordinate maintenance.

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