A study on the concept, characteristics and architecture of "Battle Cloud" in American Army

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Abstract. On the basis of in-depth analysis of the concept, development process, and main characteristics of "Battle Cloud", the architecture of the US military's "Battle Cloud" system was summarized and sorted out. From a combat perspective, the US military's "battle cloud" mainly consists of "command cloud", "strike cloud", and "support cloud". From the perspective of resource application, it can also be divided into centralized cloud, campaign thin cloud, and tactical micro cloud. The article analyzes the characteristics and advantages of battle cloud, which can provide a certain theoretical reference for the development and construction of our military's network cloud.

Keywords: Battle Cloud; Cloud Operations; Architecture

1 Introduction

The battle cloud is an elastic combat resource cluster interconnected through battlefield communication internetworking, and it is a new application of cloud computing concept in the military field [1]. The era background of the US military's proposal for the Battle Cloud is mainly to meet the strategic needs of the US military's return to the path of major country competition. After entering the 21st century, the fight in which the US military participated were carried out in a low adversarial environment where it had absolute air and information control. If absolute airspace and information advantages are lost in the future, the US military may not be able to maintain control over the battlefield [2]. Based on this, the US military proposed the concept of operational cloud in order to maintain its advantage in future fight. The deep exploration of the theory of the American War Cloud not only provides insights into the trend of military transformation and development in the US military, but also has important significance in guiding our military's military struggle preparation and combat practice in the new situation.

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2 BATTLE Cloud Concept

2.1 The Conceptual Connotation of "Battle Cloud"

The US Air Force has proposed the concept of battle cloud to address the issue of interconnectivity between fifth and fourth generation aircraft. This concept quickly gained recognition from the US Department of Defense, Navy, and other services, with the aim of addressing the threats and challenges they face and ensuring that the US military maintains an advantage in future wars [3]. The battle cloud is an elastic, dynamic, and service-oriented pool of combat resources formed by organic reorganization of dispersed deployed combat resources based on network communication technology, virtualization technology, distributed computing technology, and load balancing technology. It has the characteristics of virtualization, connectivity, distribution, scalability, and on-demand services. Its core concept is cross domain collaboration at the sea, air, sky, and network layers, emphasizing multi domain virtual existence, high integration, and natural aggregation and dispersion, achieving data distribution and information sharing within the combat space.

In 2014, Aviation Weekly in the United States released a concept map of battle clouds (as shown in Figure 1). It is composed of in orbit space reconnaissance/communication/navigation satellites, air warning aircraft, F-15/16 fighter jets, maritime aviation combat groups, and multi-dimensional combat units such as F-22/35 stealth fighters, RQ-180 unmanned reconnaissance aircraft, and new long-range bombers (LRS-B), clearly showcasing the overall concept of the US military's battle cloud [4].

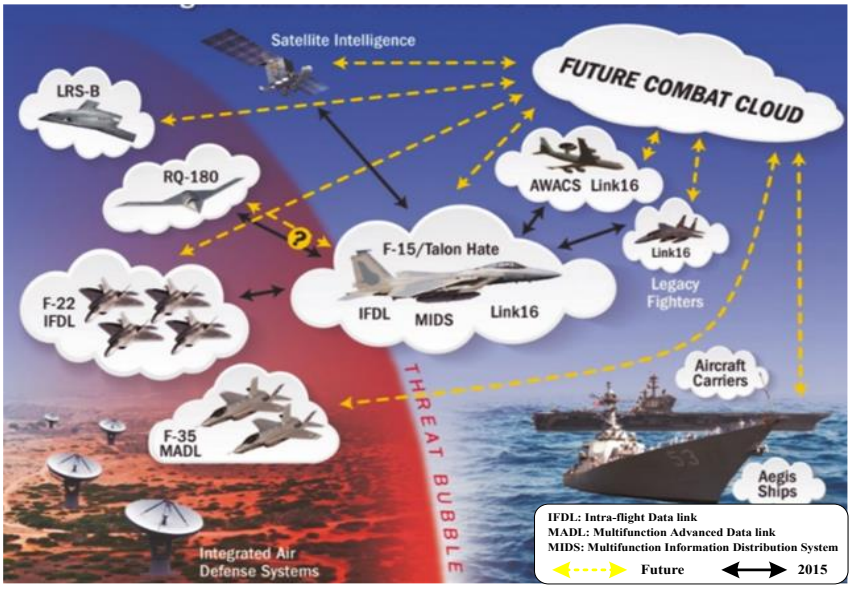

Fig. 1. Conceptual Map of US Military Operations Cloud

In fact, the US military's operational cloud is not an emerging thing created out of thin air, but an organic whole formed by the innovative reorganization of existing combat resources (intelligence resources, firepower resources, and support resources) through the comprehensive use of modern technological means. It is not fundamentally different from the "network centralization" proposed by the US military and the "information system-based systematization" concept proposed by our army. Instead, it inherits and innovates the construction and use of combat resources based on the two. In terms of construction philosophy, we have transformed tradition into something for our own use and for combat purposes, abandoning the departmentalism between military branches and various combat resources. In terms of application, it has achieved a transformation from capability based to demand based. Based on interconnection, intercommunication, and interoperability, it can complete the global organization of combat resources and the rapid restructuring of combat forces to achieve the maximum and optimal combat effectiveness. In terms of management mode, there is a shift from "separate management of each building" to "integrated and unified management", achieving the distribution, integration, and dynamic sharing of combat resources.

2.2 Development of the Concept of the US Army's "Battle Cloud"

In 2013, the US Air Force proposed the concept of "operational cloud". At this point, the concept of "battle cloud" is still in the exploratory stage, and its effective implementation urgently needs to improve related capabilities such as random access to battlefield communication, distributed storage of massive data, data mining of heterogeneous information, and rapid deployment of combat forces [5]. In 2014, the US Air Force defined the concept of "operational cloud" as the integration of intelligence, reconnaissance, surveillance, strike, maneuver, and support, achieving the comprehensive integration of current and future maritime, air, space, and network capabilities within a flexible operational framework. In 2015, the US Air Force Association proposed a new concept of integrated warfare with the "Battle Cloud". In July 2021, the US Department of Defense established the vision and goals of a cloud strategy beyond the US mainland, which aims to achieve global advantage through tactical edge "cloud" innovation. The US military's "cloud" construction based on the concept of "battle cloud" is shown in Table 1.

JWCC is a substitute for the cancellation of a single supplier cloud contract by the US Department of Defense. On December 8, 2022, the US Department of Defense awarded cloud computing contracts to four technology giants, Amazon, Google, Microsoft, and Oracle. This $9 billion JWCC contract aims to enable "cloud based" information communication and data transmission between the farthest battlefield edge and command headquarters of the US military, providing global cloud services covering all security areas to the Ministry of Defense.

Table 1. "Battle Cloud" construction of US Army

Stage	Time	Sign	Content
1	2012	《Dod Cloud Computing Strategy》	The document initially implements the transformation of DOD networks into the "cloud" , creating a flexible and secure service environment.
2	2017	JADC2	JADC2 uses a cloud architecture to build a dedicated information environment capable of providing joint global command and control services.
3	2019	New edition《Dod Cloud Computing Strategy》	The document further defines the strategic objectives and guiding principles of the U.S. military's "cloud" development.
4	2021	JWCC Project	The project can serve the global strategy of the US military in areas such as cybersecurity control measures.

From these conceptual analyses, it can be concluded that the battle cloud refers to the organic reorganization of dispersed combat resources through the comprehensive use of network communication technology, virtualization technology, distributed computing technology, and load balancing technology. It has the characteristics of virtualization, connectivity, distribution, scalability, and on-demand services.

3 The main characteristics of the “battle Cloud”

As a new application of cloud computing concepts in the military field, battle cloud has typical features such as cross domain fusion of battlefield information, distributed combat of group forces, and cross generation platform synergy. Its main characteristics are as follows.

3.1 Gathering and dispersing clouds

The battle cloud utilizes various combat platforms, sensors, various types of data, and other combat resources to link each other, constructing a networked battlefield resource pool [6]. It utilizes distributed computing technology to perform correlation analysis and prediction of massive battlefield information. It utilizes load balancing technology to achieve the overall allocation of combat resources. The dispersed and concentrated nature of the battle cloud can achieve rapid reorganization and push of various combat resources deployed in a distributed manner, thereby achieving rapid aggregation and release of combat energy. Moreover, “cloud” aggregation and “cloud” dispersion are dynamic and time sensitive, running throughout the entire combat process, and can dynamically allocate resources according to specific combat task requirements. Therefore, the cloud is in a virtual form, without any specific form, but it is ubiquitous.

3.2 Clouds come and go

The battle cloud is a networked combat system, with the “cloud” as the node, and battlefield information, resources, and situations are interconnected and interconnected through the network structure between the “clouds”. Meanwhile, as the combat process evolves, the resources enjoyed by the “cloud” will continue to expand. Various battlefield information situations are interconnected, shared, and integrated between different types and levels of “clouds”, achieving flexible utilization, reshaping, and scalability of combat resources. The interactive process of “cloud” to “cloud” can further strengthen the elasticity and inclusiveness of “cloud”, ensuring that operational resources are dynamic, rapid, and meet operational needs to the maximum extent possible. This functionality is mainly implemented using cloud technology. It can achieve real-time sharing of battlefield situation and decision support, shorten tactical decision-making time, improve the collaborative ability between unit elements and overall lethality.

4 battle cloud Architecture

A system is a collection of elements that are interconnected and interrelated to form a whole. The operational cloud architecture refers to the basic structure and formation mechanism of the operational cloud. The US military's “cloud warfare system” is a full dimensional three-dimensional warfare network based on big data, cloud computing, rapid dynamic response, and efficient collaboration. According to different classification standards, it can be divided into different battle clouds. From a combat perspective, it can be divided into “strategic cloud”, “campaign cloud”, and “tactical cloud”. From the constituent elements, it can be divided into “Command and control cloud”, “strike cloud”, “support cloud” and GIG communication network. According to scale and capability, it can be divided into “fixed cloud”, “mobile cloud”, “tactical cloud”, and “edge cloud”. It can be divided into “Army Cloud”, “Navy Cloud”, and “Air Force Cloud” according to service types [7].

4.1 Battle cloud Composition

The US military's operational cloud mainly consists of the “Support Cloud” (C-ISR), “Strike Cloud” (C-K), and “Active Control Assistance Decision Cloud” (C-ACAD). It has independent combat capabilities, as shown in Figure 2. It can be a basic combat unit, a cross domain collaborative combat group, or a node of various sizes in the "cloud warfare" network system [8].

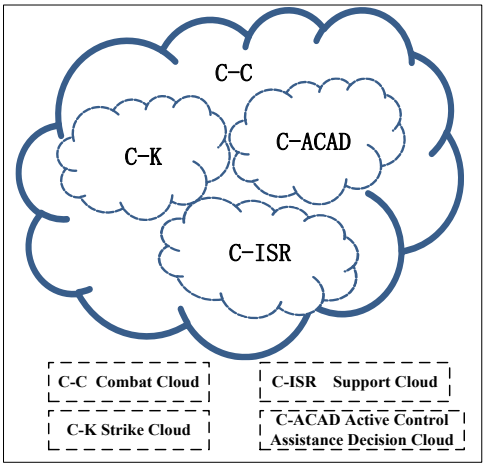

Fig. 2. Composition of Battle Cloud

4.2 Battle cloud Class

"Cloud class" is an aggregation of a class of "clouds" with the same properties. It mainly includes attacking cloud, ensuring cloud, and actively controlling and assisting decision-making cloud, as shown in Figure 3. Based on distributed deployment, all "clouds", from individual entities to systems and even the entire system, continuously enrich and integrate combat resources from bottom to top over a wide area, forming a larger scale "battle cloud". It achieves a high degree of collaboration between heterogeneous classes synchronously in the horizontal direction while providing open clustering in the vertical direction.

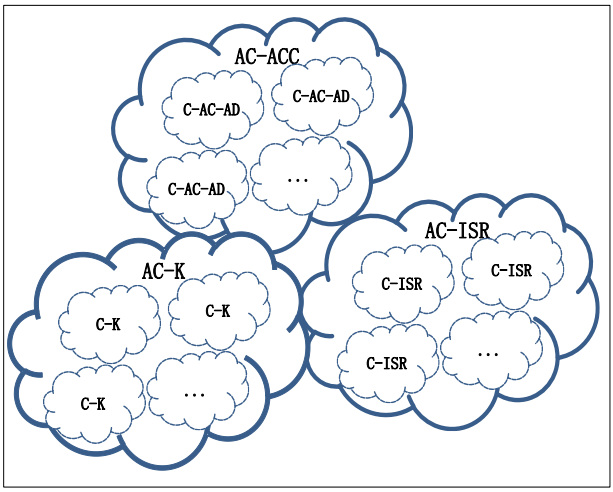

Fig. 3. Battle Cloud Class Diagram

4.3 Composition of Operational Cloud System

Overall, the basic component of the US military's battle cloud system is a "battle cloud" with relatively independent combat capabilities based on the fusion of combat forces, as shown in Figure 4. The "command cloud" is a cluster of command and decision clouds, formed by the fusion of command cloud, support cloud, and strike cloud. It can achieve a high degree of sharing and interoperability of combat resources, and transform the three-dimensional level command mode into horizontal combat coordination. Its biggest advantage is that it eliminates the vertical energy level relationship and only has a horizontal autonomous cooperative relationship. The operational resource cloud is mainly composed of three different types of clouds: centralized cloud, campaign thin cloud, and tactical micro cloud [9]. It can be divided into five layers: resource layer, capability layer, platform layer, and application layer. It achieves efficient dynamic resource management and real-time massive information processing, providing support for carrying out combat mission services and distributed resource management.

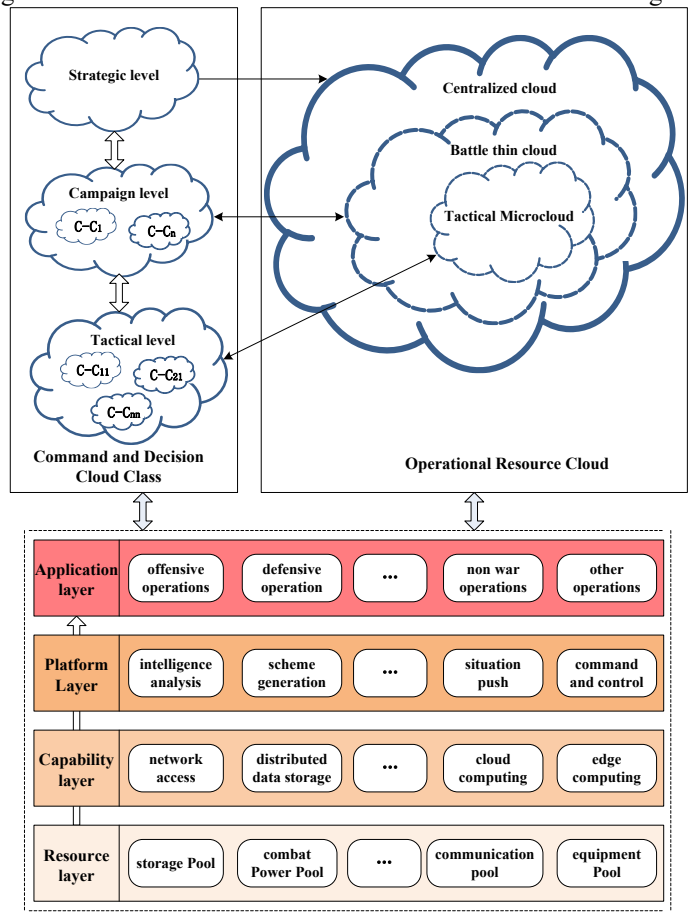

Fig. 4. Composition diagram of the US military's operational cloud system

Centralized cloud.

A centralized cloud typically relies on one or more data centers to establish a computing resource pool and provide comprehensive enterprise level computing and storage capabilities externally. Although centralized clouds can also provide services in tactical environments, they may not be accessible to tactical users due to various factors such as potential limitations in communication links, large amounts of data, and enemy attacks.

In recent years, the US Department of Defense and various military services have adopted methods such as "merging, transitioning, and stopping", gradually integrating the existing data centers into four categories based on their hierarchical and functional functions. It is mainly divided into core data centers (CDC), military facility processing nodes (IPN), specialized processing nodes (SPPN), and tactical processing nodes (TPN). As shown in Figure 5. There are two main benefits of doing so. One is to reduce the exposure of attacks throughout the system and enhance security. The second is to reduce energy, equipment, and space costs, and achieve consistency in IT architecture.

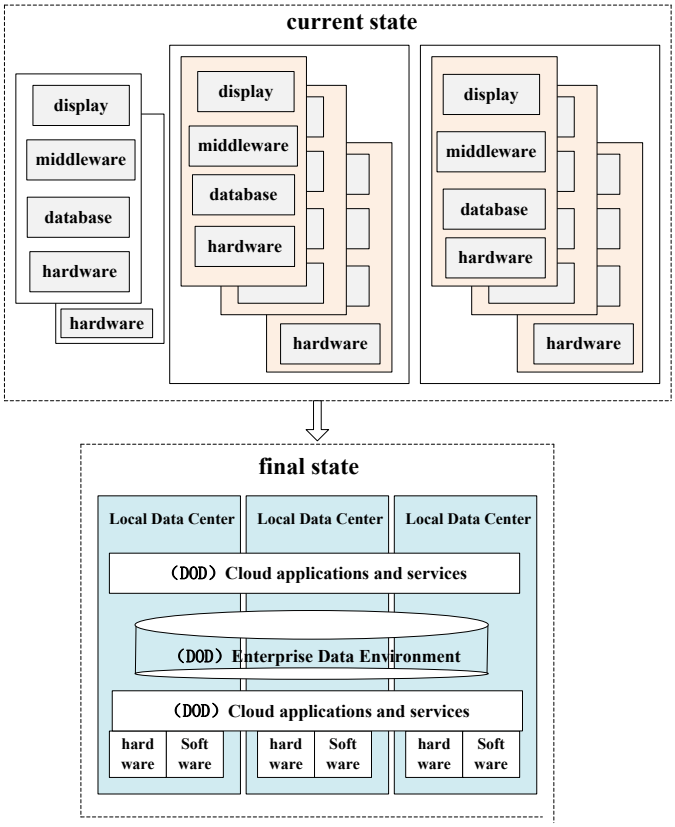

Fig. 5. Centralized cloud data center transfer

Battle thin cloud.

Battle thin clouds are clouds equipped on helicopters or tanks, capable of following troops for maneuvers, providing high-performance, low latency computing and communication interaction capabilities within one hop for individual mobile devices. It can create a communication dome of 20-30km, providing cloud computing capabilities for troops of around 200 people.

The concept of tactical thin clouds was proposed by the Software Engineering Research Institute of Carnegie Mellon University in 2012. Tactical thin cloud refers to a small, discoverable cloud data center that can be deployed on vehicles or other platforms ahead. The tactical thin cloud architecture mainly includes the "thin cloud" host, client, and management platform, as shown in Figure 6. Thin Cloud adopts a pre-configured mechanism using Avahidaemon as a service.

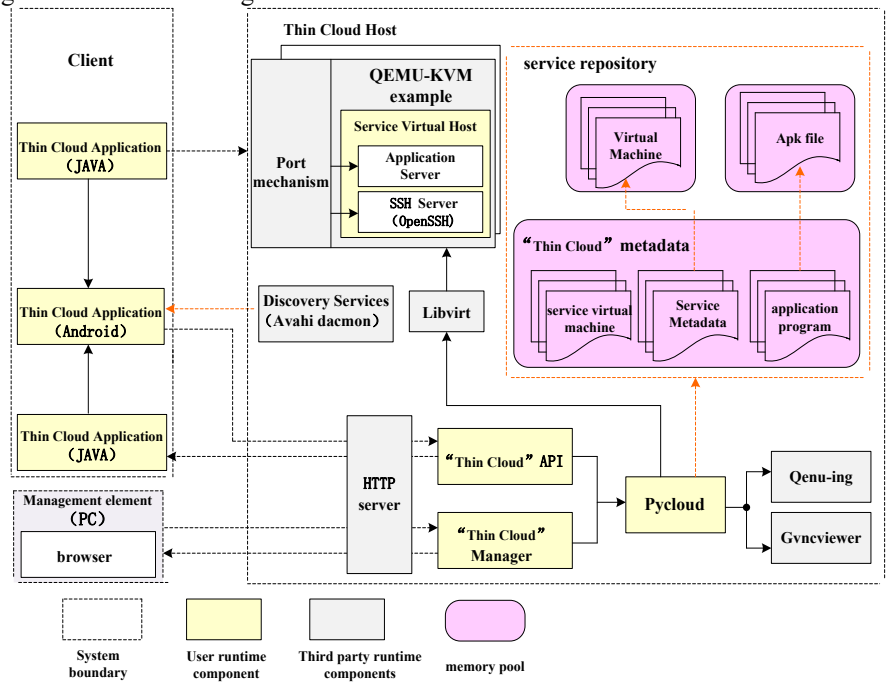

Fig. 6. Tactical Thin Cloud Architecture

Tactical micro cloud.

Tactical micro clouds achieve virtual mobile cloud computing capabilities through adaptive networking, allowing mobile devices to share computing and storage resources, collaborate in processing collected data, and share situational information. MicroCloud provides the ability to process data at the tactical edge and take immediate action based on the results of data processing. However, due to the limited processing and storage capabilities of mobile devices, they are not suitable for complex calculations and large amounts of processing. For example, the Army's Knight Warrior end-

user equipment is equipped with tactical attack kits and other tools. It can be connected to digital radio stations through a USB interface and can also receive images sent by small drones, forming a battlefield wireless network [10].

In short, from the perspective of various cloud applications in the US military, its essence is to exchange the simplicity of the operational systems in the physical and cognitive domains by increasing the complexity of the information domain. By rationalizing the control relationship, call relationship and data transitive relation among the operational elements, and by virtue of cloud-based collaboration, inter cloud collaboration and intra cloud collaboration architecture, it can achieve wide coverage, low coupling, high cohesion, and strong elasticity.

5 Enlightenment from the Development of the US Army's "Battle Cloud"

From the perspective of US military tactical cloud and other applications, its essence is to achieve "strong elasticity" through cloud collaboration and intra cloud collaboration architecture. This has clear reference significance and important reference value for the construction of a network cloud integration system for resource reuse and unified management and maintenance in our army.

5.1 Building a network cloud integration support system

We should be guided by efficient support for joint combat operations, with a cloud platform with resource coordination as the core, and achieve dynamic reconstruction of cloud to cloud, cloud edge, and cloud network, forming an integrated and interconnected network cloud integration service support system. By building, connecting, and using clouds around combat operations, a hub for information transformation and nodes for information dissemination are constructed, forming a networked "battlefield resource pool".

5.2 Building an information and communication guarantee system

Relying on the cloud architecture, we vigorously build wireless communication methods that are compatible with mobile networks, satellite networks, data link networks, and others. We develop onboard and airborne cloud nodes that can be dynamically restructured according to the needs of the battlefield, achieving seamless connection between the "sky, earth, and sea". We need to provide interactive services such as precise information assurance, remote collaborative operations, and cross domain collaboration.

6 Conclusions

The operational cloud will be integrated with new operational concepts to support the future operational landscape. The new combat concepts represented by mosaic warfare and multi domain warfare are accelerating, and the battle cloud, as a fundamental and critical construction project that various services are striving to promote in the future, is quietly undergoing changes. Therefore, based on comprehensive checks and balances against strong enemies, we should comprehensively promote and deepen reform. We should accelerate the research and planning guidance of the requirements for building our military's operational cloud, actively promote the implementation and practical verification of various service and arms' operational cloud, and gradually form a unique “cloud warfare” model of our army.

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