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AGILITY FACTORS ANALYSIS FOR FINANCIAL PLATFORM ENTERPRISES UNDER CLOUDBURSTING ARRIVALS

Juan CHENG[1], Tao LI[2,3]*

FinTech brings challenges and opportunities for digital transformation of traditional financial enterprises, giving rise to FinTech Platform Enterprises (FPEs). Open-source based cloud computing architectures empowers FPEs with big data storage and massive real-time computing, catches focus of academia, however, lacks research on data agility. This study describes features of FPE's cloud computing architecture, then models and discusses agile factors under cloud bursts. This study contributes to managerial decision of FPEs using hybrid cloud under resource constraints and is useful for theoretical researchers and practitioners.

Keywords: FinTech; Financial Platform Enterprise; Data Agility; Cloudbursting; Hybrid cloud

1. Introduction

FinTech enhances accountability, improves efficiency, and empowers FPE while disrupting traditional business models with access to distributed cloud computing platforms [1]. JD.com, Amazon, and Ant Group - Alipay are leading in FinTech, with commercial banks developing FPEs or partnering with FinTech startups [2]. FinTech companies benefit from cloud computing as it provides affordable and accessible high-value computing services and resources, in line with Moore's Law [3]. With continuous evolving, new architectures such as BaaS, FaaS, DaaS, and NaaS have emerged, leading to cost-saving benefits and increased agility for organizations[4, 5]. However, complexity of diverse distributed cloud computing architectures also results in higher infrastructure Op&Dev costs. Cloud computing improves security and efficiency at application layer [6]. Cloud providers such as AWS and AliCloud play significant role in expanding the market by leading FPEs to adopt "logically centralized, physically decentralized" model of fog, edge, and cloud computing [7]. Increase of cloud providers offers options and

[1] Prof., School of Business, Xianda College of Economics & Humanities Shanghai International Studies University; Hongkou District, Shanghai, China, e-mail: 1110210@xdsisu.edu.cn
[2] Lecturer, School of Business, Xianda College of Economics & Humanities Shanghai International Studies University; e-mail: 1911025@xdsisu.edu.cn
[3] Ph.D., School of Intellectual Property, Nanjing University of Science & Technology; Assistant researcher, Centre for Innovation and Development, Nanjing University of Science & Technology, Nanjing, China, * Corresponding author, e-mail: shiny943@163.com

brings uncertainty [8]. This study has theoretical contribution and practical value for FPEs to make management decisions in hybrid clouds with limited resources.

2. Related Works

FinTech uses Artificial Intelligence, Blockchain, Cloud computing, big Data and Internet of Things to improve efficiency and reduce costs in financial services[9]. Fintech promotes financial and social inclusion in developing countries [10] reduces resource allocation inefficiencies in the banking sector [11], and maintains the stability of the banking system [12]. FinTech platform model removes barriers of time and space by implementing artificial intelligence and sophisticated software to capture, analyze and exchange big data[13]. At its core, it is an internet-based participatory infrastructure that facilitates the exchange of products, services, or currencies to create economic value for all participants [14]. Customer-centered strategies, i.e., experience-based offerings (EBO) [15], offer solutions for gaining competitive advantage in the financial services industry [16]. These findings extend the conceptual model of platform and can be used to achieve goals of FPEs. Cloud computing provides technological foundation i.e., server hosting, payment gateways for FPEs [17]. Cloud computing has been widely deployed in recent years and the on-demand model has reduced the pressure on infrastructure spending[18]. Hybrid clouds provide commercial banks and FPEs with the ability to control critical operations through private clouds and minimize operational costs through public clouds[19]. Previous studies on pricing issue [20] are informative for cloud managerial decisions of FPE. Cloudbursts, which use external computing resources from public cloud to meet sudden increases in demands of private cloud, catch the attention of scholars [21]. Limitation exists in the infinite capacity of the cloud computing model[22], which is filled by the study of user data protection risks under cloud bursting[23]. In addition, although dynamic pricing-based combinatorial auction mechanisms are used to cope with sudden increases in cloud computing demand[24], efficiency in responding to large-scale influxes in computing and storage demand lacks discussion. The above literature review suggests agility depends on IT alignment in response to sudden cloud demand. Hence, agility under cloudbursts requires being studied.

3. Features of FPEs' Architecture

Digital transformation of PSBC (Postal Savings Bank of China) is a case to illustrate features of LC (Logical Centralization) cloud architecture. Simulation for cloudbursts Data Agility is conducted in section four.

3.1. Evolution Phases

PSBC's operational system has evolved through three main phases (Fig 1).

Phase one from 2000 to 2014: Data centers of each branch remain independent, mainly a manual data silo model.

Phase two from 2015 to 2021: LC (Logical Centralization) breaks down data silos, connecting data, centralizing processes, desensitizing privacy.

Phase three from 2022 onwards: Distributed highly available parallel computing hybrid cloud architecture provides financial products and services in a customer-centric manner.

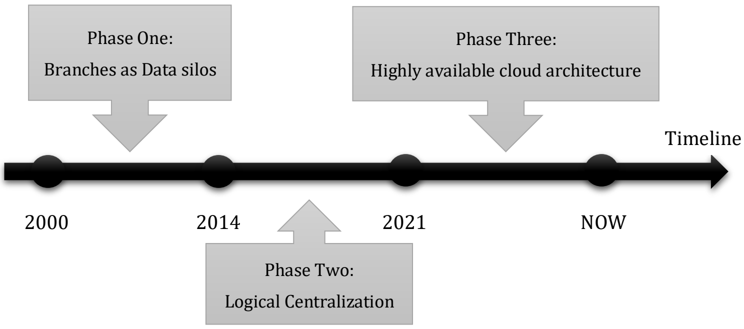


Fig 1. Evolution Phases of PSBC's FinTech Operational System

3.2. LCRCS Architecture

LCRCS is Logical Centralized Responsibility Center System Architecture. A branch is a responsibility center that is used as the starting point to adapt the branch's operational system to meet consistency, efficiency, security, and integrity, while considering technological foresight to financial services (Fig 2). Top layer of LCRCS is a data center containing following modules. (1) Risk management module aims to monitor and manage various risks faced by financial institutions. (2) Operation management module automate and optimize the business processes. (3) Accounting module is responsible for accounting and financial management, supports various accounting standards and tax laws. (4) Product & service module handles comprehensive life cycle management of financial products and services. (5) Human resources module contains recruitment, performance, and salary. (6) Managerial decision module supports senior management in making strategic and sustainable decisions. The middle layer of LCRCS is responsible for processing and management of business data, contains the following modules. (1) Client information module stores and manages bank customer data to provide various services. (2) Integrated operational system contains sub-modules: a) Billing system manages customer billing and charges; b) Product system oversees loans, deposits, credit cards, wealth management. c) Transaction system handles transfers, remittances, and payments. d) Order system maintains the integrity of records. (3) Business modules consist of: a) Fund custody sub-module manages account opening, clearing, and settlement. b) Risk control sub-module oversees bank risk control and management. c) Loan approval sub-module manages loan business. d)

Note flow sub-module handles application, acceptance, and discounting. e) Wealth management sub-module offers investment consulting, asset allocation. f) International business sub-module manages foreign exchange, international trade financing, and overseas investment. Bottom layer of LCRCS contains Directory service, B2B/B2C Portal, Database, and Data service platform: (1) Directory service module ensures system security and data integrity by offering authentication, authorization, and authority management services. (2) B2B/B2C Portal module offers account inquiry, transfers, credit card applications, etc, through user interfaces and interaction design solutions. (3) Database module serves as centralized data storage and management center with high reliability, performance, and flexible storage solutions. (4) Data service platform module provides efficient data services, integration capabilities.

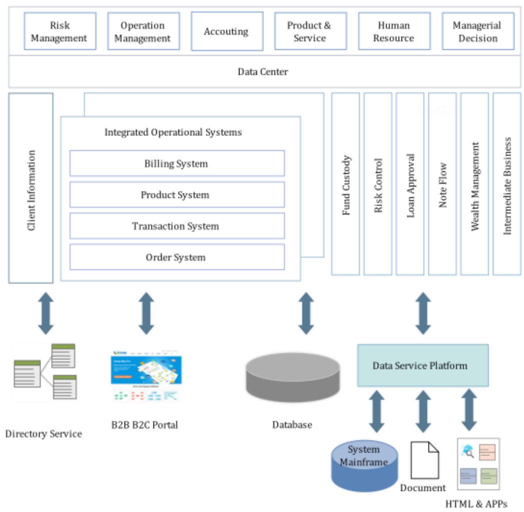


Fig 2. LCRCS Architecture

3.3. LCTC Architecture

LCTC is Logically Centralized Transactional Computing Architecture. Logical centralization mainly centralizes transactions in Branch Front-end System (BFS), Counter Channel Front-end System (CCFS) and Operational Processing System (OPS) (Fig 3). BFS and CCFS are front-end systems offering counter services and basic banking operations. CCFS processes physical channel business, while BFS focuses on electronic channels from the internet. OPS supports deposit, loan, transfer, and clearing, with quick responds across multiple systems. In sub-layer, ATM, APP, Phone and Online banking allows self-service. Permission management specifies teller permissions and transaction limits ensuring standardized transactions; authorized tellers manage tail box for storing cash exceeding counter cash box limit.

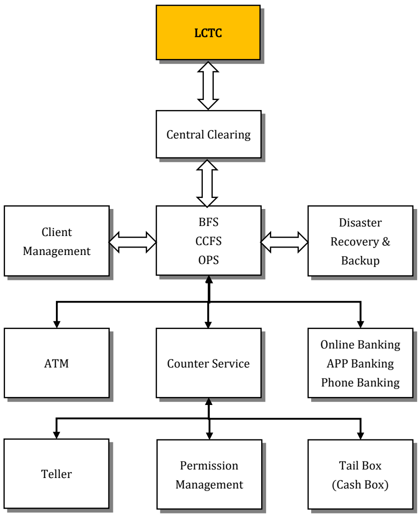


Fig 3. LCTC Architecture

3.4 Parallel Transaction

Parallel transaction (PT) improves system throughput and concurrency by executing multiple transactions simultaneously with intersecting control processes, data access, and operation execution. In PSBC's FinTech, PT partitions data table into separate data blocks, executes them in parallel using different threads, and aggregates results produced by the worker threads through a message queue, supporting parallel scanning, aggregate computation, sorting, join computation, etc. (Fig 4).

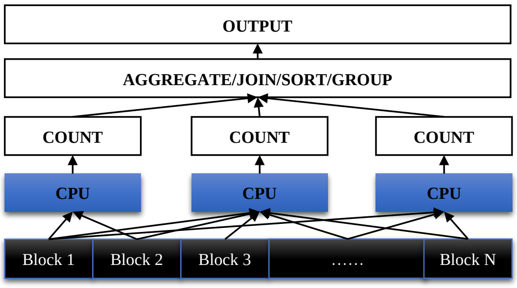


Fig 4, Parallel Transaction Architecture

4. Cloudburst Simulation

4.1. Premises

FPEs face cloudbursts scenarios caused by e-commerce shopping festivals i.e., Cyber Monday, Black Friday in U.S. or Double Eleven, Eighth June in China, and need to consider the read/write performance of accessing computing and storage transactions across different types or architectures of clouds. When FPE is configuring a hybrid cloud, costs are correlated with factors such as cloud type and cloud capacity. Numerical simulations can reduce the risk of trial-and-error costs and serve as a reference for FPE cloud management. Based on Henneberger (2016) [25], assumptions and parameters are setup for simulation of the FPE cloudburst problem.

Assumption 1: Probability distribution of transaction demand can be estimated.

Assumption 2: Any cloud computing demand be partitioned to the demand for private cloud infrastructure construction or public cloud leasing.

Assumption 3: Different types of clouds lead to different market prices for private and public clouds.

Assumption 4: FPE's objective is to determine the optimal private and public cloud capacity mix that minimizes the aggregate cost of cloud services, given known public and private cloud prices.

Symbols and descriptions are explained in Table 1.

Table 1

Symbols and Descriptions

No.	Symbol	Description
1	x	Computing demand per unit of time. Appropriate capacity and configuration required for system or application.
2	$f(x)$	Probability density of cloud access transaction x. Possibility of users accessing cloud resources at different points in time
3	$F(x)$	Cumulative distribution of cloud access transactions . Cumulative probability of transactions occurring before a specific time point.
4	c	Private cloud capacity. Computing capacity available for cloud services in private infrastructure
5	k	Private cloud price - quote by unit capacity. Depends on hardware and software, customization and vendor support.
6	p	Public cloud prices are quoted by hourly usage rates
7	g	Contracted cloud service levels Vendors offer varying support, performance and uptime guarantees.
8	k_a	Loss of work stoppage due to breach of contract, Compensation for costs and losses under the articles.
9	z	DA cost per unit storage capacity Costs incurred in deploying hybrid cloud infrastructure for data agility.
10	t	time

4.2. Baseline Model and Simulation

Private cloud is constructed as part of FPE's fixed assets and uses U.P.S. and disaster-tolerant backups to prevent data and user loss. Cloud-based solutions utilize distributed database management systems with advanced replication and fragmentation mechanisms to ensure data reliability, high availability, and seamless disaster recovery, offer scalable storage and processing capabilities, as well as built-in redundancies for protection against data loss and service disruptions. Hence, cost of private cloud has the form,

$$TC_{private} = k \cdot c \tag{1}$$

where k stands for price of private cloud per storage unit, and c stands for the capacity of private cloud. Public clouds under operating leases contract is affected by objective force majeure, i.e., power outages, network maintenance, natural disasters, etc. Consider total usage cost of public cloud denoted as TC_{public} below,

$$TC_{public} = C_{leasing} + C_{abnomal} \tag{2}$$

where C_{lease} stands for the sum of lease cost in the normal case, and $C_{abnomal}$ stands for the loss in the abnormal case. Overflow private cloud storage and compute demand leads to leasing costs and anomaly costs for public clouds. Hence, leasing cost C_{lease} and loss of public cloud $C_{abnomal}$ are respectively obtained as follows.

$$C_{leasing} = g \cdot t \cdot \left(\int_c^{\infty} f(x) \cdot (x - c) \cdot dx\right) \cdot p \tag{3}$$

$$C_{abnomal} = (1 - g) \cdot t \cdot \left(\int_c^{\infty} f(x) \cdot (x - c) \cdot dx\right) \cdot k_a \tag{4}$$

The objective function for the total cost, denoted as TC, is expressed as the minimization form of the sum of total usage cost of public cloud and total usage cost of private cloud, which is given below.

$$\min TC = TC_{public} + TC_{private} \tag{5}$$

By considering the price of public cloud per storage unit, denoted as p, and loss of work due to public cloud outage k_a, equation (5) is expanded to the following equation.

$$\min TC = k \cdot c + (g \cdot t \cdot p + (1 - g) \cdot t \cdot k_a) \cdot \int_c^{\infty} f(x) \cdot (x - c) \cdot dx \tag{6}$$

To consider the optimal capacity level of the private cloud, equation (6) is differentiated in terms of the private cloud capacity c, which gives

$$\frac{\partial \min TC}{\partial c} = -\int_c^{+\infty} f(x) \cdot dx \cdot (g \cdot t \cdot p + (1 - g) \cdot t \cdot k_a) + k = 0 \tag{7}$$

where the differentiation is equal to 0 to obtain the extremum. The private cloud optimal capacity, denoted as c^*, is obtained by the inverse function as below.

$$c^* = F^{-1}\left(1 - \frac{k}{gpt + k_a(1-g)t}\right) \tag{8}$$

Further, based on equation (7), second-order partial derivative is constantly positive, and its total cost is convex, giving equation (9) below.

$$\frac{\partial^2 \min TC}{\partial c^2} = (g \cdot t \cdot p + (1-g) \cdot t \cdot k_a) \cdot f(x) > 0 \tag{9}$$

Numerical simulation is a practical technique in cases where large-scale experimental conditions are limited.

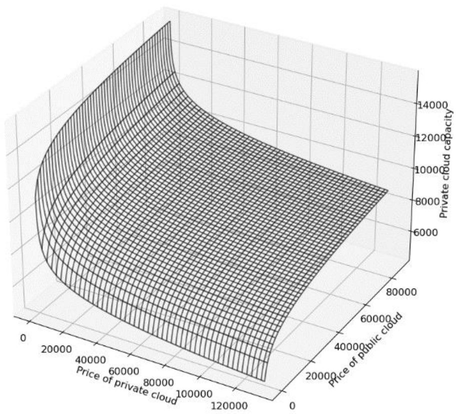
Assuming an exponential distribution of access transactions to the cloud as

$$f(x) = \lambda e^{-\lambda x} \tag{10}$$

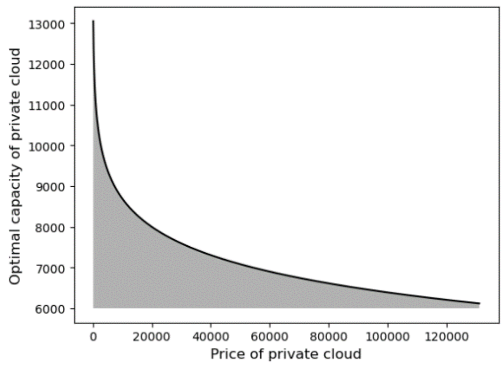
Where x stands for storage and computing demand per unit of time, and λ is a parameter for an embodiment of the rate in the exponential distribution, which portrays the rate at which random events of accessing demand that occurs in the hybrid cloud. Hence, private cloud optimal capacity in equation (8) is specified as below.

$$c^* = -\frac{\ln\left(\frac{k}{gpt+k_a(1-g)t}\right)}{\lambda} \tag{11}$$

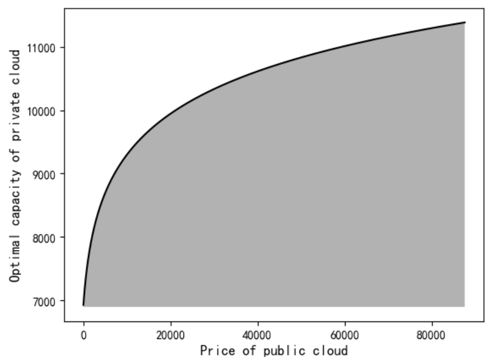
Price plays a vital role in managing cloud infrastructure. Taking Huawei hybrid cloud as an example, assuming hardware differences in private cloud access bandwidth, number of processor cores, etc., the annual price with range for a capacity of 128TB is 1,000 CNY to 200,000 CNY. The public cloud has an annual price with range from 1,000 CNY to 10,000 CNY depending on differences in ease of backend management, security, etc. The performance rate for the contracted service level is 0.99%, the loss per hour of downtime assumes $100,000, the decision coverage time tends to infinity, and the exponential distribution parameter λ = 0.005. Fig5(a) shows the surface composed of private cloud price, public cloud price and private cloud capacity. The surface is profiled separately to obtain the relationship for private cloud optimal capacity and the other two variables (Fig5(b) & (c)).



(a) Price of public cloud, price of private cloud and capacity of private cloud



(b) price of private cloud on private cloud capacity



(c) price of public cloud on private cloud capacity

Fig 5. Price of private cloud, price of public cloud, capacity of private cloud

4.3. Cloudburst Model and Simulation

FPEs often prefer hybrid clouds due to flexibility, where applications primarily run on private resources but can switch to the public cloud during peak computing demand, which referred to cloudbursts[21]. Capacity margins of public cloud enable sudden bursts being handled, refer to Data Agility (DA), which is quantified through equations and simulation below. Variable z denotes the DA cost per unit storage capacity among different types of cloud computing architectures, and variable g stands for the cloud service level contracted. The DA cost, denoted as C_{DA}, is calculated as below.

$$C_{DA} = g \cdot z \cdot \int_{c}^{\infty} f(x) \cdot (x - c) \cdot dx \quad (12)$$

Total cost (TC) is expressed as follows.

$$TC = TC_{public} + TC_{private} = \left(C_{leasing} + C_{abnomal} + C_{DA}\right) + TC_{private} \quad (13)$$

Still assuming an exponential distribution of cloud computing transactions, the total cost TC is partially derivatized against the private cloud storage capacity c.

$$\frac{\partial TC}{\partial c} = k - e^{-\lambda c}(gpt + gzt + (1 - g)k_a t) \quad (14)$$

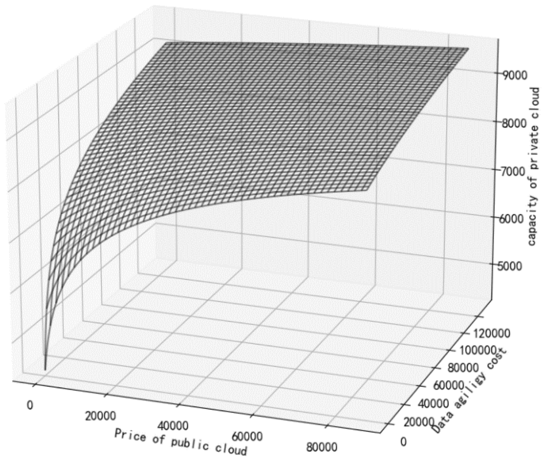
The optimal capacity of a private cloud is given via equation (14) being equal to zero.

$$c^* = \frac{\ln\left(1 - \frac{k}{gpt + gzt + k_a(1-g)t}\right)}{-\lambda} \quad (15)$$

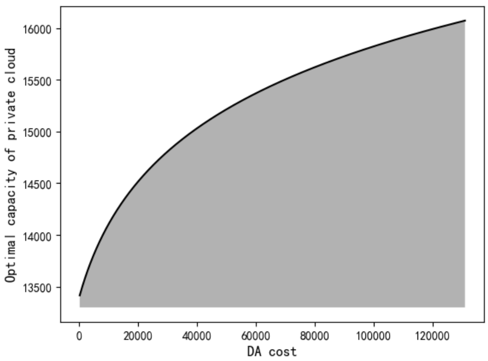
Partially derivatize the total cost TC against DA cost z, which gives

$$\frac{\partial TC}{\partial z} = g \cdot t \quad (16)$$

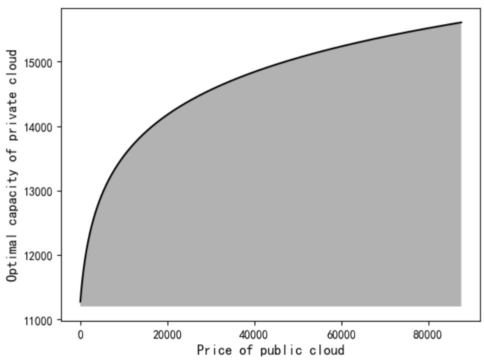
Fig6(a) illustrates the surface composed of the relationship between private cloud price, private cloud capacity and Data Agility (DA) cost. The surface is profiled separately in Fig 6(b) and in Fig 6(c), to obtain the relationship between the optimal private cloud capacity and the other two variables.



(a) Data agility cost, price of public cloud, capacity of private cloud



(b) DA cost on capacity of private cloud



(c) price of public cloud on capacity of private cloud

Fig 6. DA cost, price of public cloud, capacity of private cloud

5. Conclusion

In the massive influx of business data caused by the e-commerce shopping festival, the load capacity and scalability of the cloud computing architecture of FPE will be severely tested, and the financial business operation and management of the platform will be challenged. In this study, data agility of FPEs is discussed. This study firstly demonstrates the characteristics of cloud computing architectures based on an FPE case, and secondly analyzes optimal private cloud capacity and DA cost via numerical simulations. The research gap is filled, which can help platform companies using hybrid cloud computing to make decisions under data or resource constraints, and is informative for theoretical research and practice. In the future, commercial banks will respond to the cloud explosion through big data computing and storage technologies, including cross-region highly available deployment of data, multi-region and multi-version storage of data, multi-tenant management, and cross-cloud computing engines to meet the needs of big data applications.

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