



Intercloud Resource Discovery: A Future Perspective using Blockchain Technology

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ARTICLE INFORMATION

Received: September 4, 2019

Revised: September 26, 2019

Accepted: October 10, 2019

Published online: October 25, 2019

Keywords:

Intercloud, Challenges in resource discovery, Blockchain technology

ABSTRACT

Intercloud is a single logical entity orchestrating resources from different individual clouds providing on-demand resource provisioning in a seamless manner. However, achieving efficient resource discovery in the intercloud environment remains a challenging task owing to the heterogeneity of resources and diversity of cloud platforms. The paper briefs about intercloud resource discovery, outlines the current work done using existing approaches and examines the challenges involved. Finally the paper explains the concept of blockchain and presents an innovative conceptual model for efficient resource discovery in intercloud.



DOI: [10.15415/jtmge.2019.102008](https://doi.org/10.15415/jtmge.2019.102008)

1. Introduction

Intercloud (Bernstein, 2009) as discussed by Cisco is an interconnected global “Cloud of Clouds” allowing individual clouds to share the common pool of resources to handle flash-crowd scenarios and provide services in the geographic proximity of end-users. However, discovering resources effectively by individual CSPs is one of the most important and complex operation within the intercloud environment. Collaborating CSPs to allow seamless cross-utilization of resources and services and to make optimal choices that meet dynamic resource requirements is thus the need of an hour. Data centres of various CSPs and the end-consumers are geographically dispersed leading to latency issues and hence can become the major challenge. Even the security issues within the intercloud environment are a serious concern. Most cloud vendors are working on providing solutions that can manage resource orchestration across multiple CSPs but research in this field is at its very early stage. Hence, effective intercloud resource discovery strategy must be developed to handle latency and security issues resulting in improved cost to performance ratio for all the stakeholders within the intercloud environment.

The rest of the paper is organized as follows: A generic system model for the intercloud resource discovery with the major actors involved is explained first.

Then the existing strategies proposed by researchers to handle resource discovery in intercloud and challenges involved are also covered. The paper presents the concept of blockchain technology focusing on main features involved. An innovative and a new idea of blockchain is used in proposing a model for effective resource discovery within the intercloud environment. In the end, conclusion of the paper is presented.

2. System Model

Resource discovery in intercloud environment can be defined as a process that involves efficient on-demand search for resources/services (whether computing or storage) across all stakeholders i.e. cloud service providers (CSPs), service providers (SPs) or users in the intercloud.

- (a) Cloud Service Provider (CSP) provides resources and services to its customers and other CSPs in the intercloud.
- (b) Service Provider (SP) is the third-party vendor that consumes the infrastructure of the CSPs to offer their own value added services to accommodate the needs of their users.
- (c) Users are the end clients of the resources, platforms or services offered by the CSP or the value-added services of the SPs.
- (d) Brokers are responsible for orchestrating the operations

across CSPs, SPs and Users acting as a middle-man, hence important for the seamless operation of the intercloud.

The four main steps covering the major operations involved in resource discovery can be represented as shown in Figure 1 below. The diagram explains the key tasks performed for accomplishing the resource discovery process within the intercloud environment taking into account the activities performed by the key players.

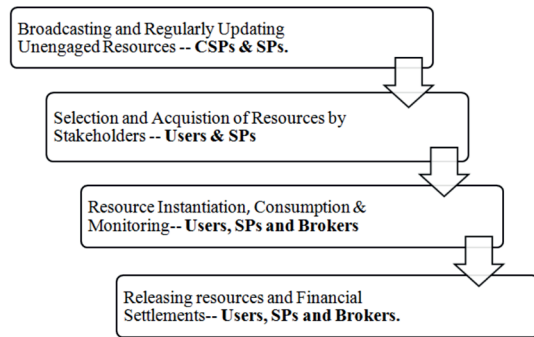


Figure 1: Resource discovery process using stakeholders

Figure 2 broadly explains the two-level schematic representation showing the various stakeholders involved in intercloud resource discovery process. It includes the intercloud interface layer and intercloud orchestration layer representing a centralized model. The intercloud interface layer involves broker for handling the resource requests from the users or the SPs whereas the intercloud orchestration layer is responsible for handling and orchestrating the resource requests within the CSPs again using broker as a middle-man. Our proposed model provides an alternative P2P-based approach using innovative idea of blockchain in which the CSPs would interact with each other directly without requiring any central entity and hence the interface layer or the orchestration layer as shown in the figure would no longer be required.

2.1 Resource Discovery Approaches for Intercloud

There are four main categories for resource discovery within intercloud environment which can be explained as follows:

2.1.1 Broker-based Approach

Broker based approaches have been the most prevalent technique for discovering resources in the cloud environment.

Brokers act as a middle-man between the stakeholders including cloud users and the CSPs/SPs which help the users to choose resource/services that best meet their requirements. Researchers in (Buyya R. 2009) have acknowledged the importance of cloud brokers and their multifarious responsibilities. Inter-Cloud Framework (Buyya R., 2010) suggests a centralized architecture built around a central entity called Cloud Exchange. The other

members of the architecture include Cloud Broker and a Cloud Coordinator. SLA-based tiered pricing model (Nair, S. K., 2010) proposes a cloud broker that provides broker service to assign identity management, access management, policy enforcement, and audit capabilities to stakeholders like CSPs.

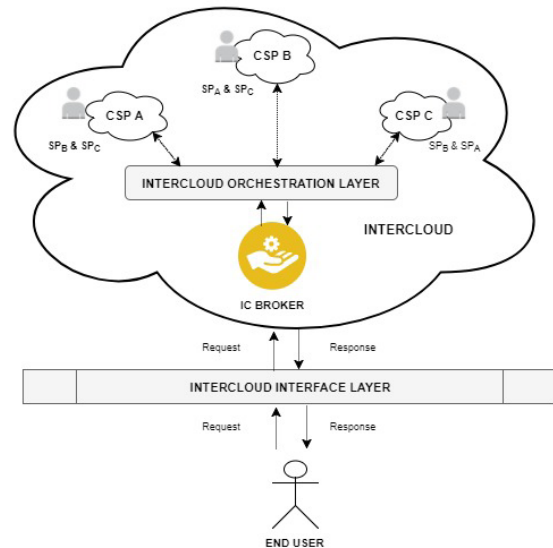


Figure 2: System model using key actors

Predicting QoS compliance of potential resources is proposed in CloudRank Framework (Zheng Z., 2013). In this framework, different values are gathered from varied users using same cloud service and finally ranks are predicted based upon the ability to meet QoS parameters. Many companies like Dell have shown a keen interest in cloud services brokering, and have been continuously working in partnership with VMware to drive through the same (Stickeleather J., 2011).

2.1.2 P2P-based Approach

Due to its extreme scalability, resilience and fault-tolerance, P2P model qualifies and is a right fit for adoption within intercloud environment. Resource discovery mechanisms using centralized approach may not scale well and might lead to issues like performance bottlenecks and single-point-of-failure but P2P-based discovery mechanisms are naturally scalable. Non-federated model proposed by authors in (Gupta A., 2011) explains the use of feasible strategy for creating a pool of cloud service providers for meeting volatile resource requirements. Authors in (Kapoor L., 2013) propose a chord-based resource discovery mechanism using P2P brokers based on spatial-awareness of cloud data-centers associated with different cloud service providers thus permitting QoS-compliant resource provisioning within the intercloud domain.

Few references using P2P based resource discovery approach has been noted and hence its potential is still

not fully utilized. Inclusion of this approach shall play a significant role in developing efficient resource discovery techniques within intercloud domain.

2.1.3 Agent-based Approach

Agents work on behalf of another entity and exhibit properties of autonomy, pro-activity, communication and negotiation, enabling completion of a task. Use of agents for resource discovery and management of resources including CSP-CSP and CSP-SP, SLA negotiations is entirely rational. Cloudle (Sim K. M., 2009), an agent based search engine supports similarity reasoning, compatibility reasoning, and numerical reasoning by consulting cloud ontology for regulating the likeness between providers' and consumer's service specifications. Agent-based computing explains that agents are the most appropriate mechanisms for automating complex interactions within an intercloud environment and hence play an important role in creating the intelligent intercloud vision (Sim K. M., 2010).

2.1.4 Ontology-based Approach

Ontology is a common vocabulary that promotes sharing of information in an intercloud domain and resulting in meaningful search. The main objective of an intercloud CSP is to provide surplus computing resources and total transparency while providing visibility of the resources at the same time. This ensures that the resources/services are able to meet compliance and match with the functional, architectural, policies and constraint requirements of other cloud service providers. Current work in this domain is focusing on defining declarative semantic model/language which captures both requirements and constraints of computing resources. Multi-layer ontology (Lie Z. H., 2016) is proposed to solve the complications of cloud resource discovery in connected environment of multiple providers by selecting the resources that best meet the requirements.

A summary of different strategies/approaches illustrating work done by researchers for intercloud resource discovery is discussed below in Table 1.

Table1: Resource discovery approaches

Resource Discovery Approaches & Description	
Broker Based Approach	
Market-Based Negotiation Model (Buyya R. 2009) (Buyya R., 2010)	Focus on federation of clouds and the resource discovery process is based on negotiation between stakeholders organized as a centralized architecture. Suffers from issues of single point of failure and scalability issues.
Architecture on Meta-Computing Scheduling (NWIRE) (Schwiegelshohn U., 1999)	Emphasize on brokerage and training and proposes a market-based system between sub-domains. Ensures high degree of flexibility.
SMI Cloud Framework (Garg S., 2013)	Authorize customers to analyze cloud offerings provided and ranking them based upon their ability to meet the user's QoS requirements. The Ranking algorithm proposed is in-efficient to handle variations in QoS attributes such as performance, reliability etc.
Architecture established on Clustering of Resources (Sotiriadis S., 2012)	Proposes architecture that focuses on clustering scheme based upon previous resource requests. Clustering scheme is organized on putting together transient services but suffers from issues of creating and disbanding of the clusters. Keeping track of past service experiences of each involved participant may incur overheads.
P2P Based Approach	
C2C Framework (Gupta A., 2011)	Market ecosystem based on P2P approach facilitates resource sharing within dispersed CSPs providing greater elasticity and handling volatile resource/service requests. Model caters to small to medium CSPs and simplifying assumptions made can further incur complexities into the model demanding end-to-end settlements within multiple dispersed CSPs.
P2P-Based Distributed Resource Discovery (Kapoor L., 2015)	Resource discovery mechanism is based upon spatial-awareness of data centers belonging to various CSPs and minimizes required response time. The approach is silent about QoS parameters like availability, reputation etc. which is required for resource/service discovery and selection mechanism.

Chord Based Resource Discovery (Kapoor L., 2013)	Chord-based distributed resource discovery mechanism is explained again based upon spatial-awareness of cloud data-centers which belong to different dispersed CSPs. Elements of trust and reputation calculation are not considered.
Ontology Based Approach	
FIDDLE: Semantic Information Model (Willner A., 2015)	Explains federation of CSPs including infrastructure and also life-cycle of resources/services recommended. But the underlying concept described in the model is currently in the process of being standardized by an international consortium that is independent of specific research projects or products.
Multi-layered Ontology Scheme (Lie Z. H., 2016)	Proposes a Multi-layer ontology scheme from software developer requirements view point. Technical limitations of single CSP are covered in the research but the bi-dimensional matching algorithm for resource discovery model is nominated to search for more such resources.
Agent based Approach	
Agent-Based Cloud Commerce (Sim K. M., 2009)	Agent-based test-bed is responsible for making decisions, managing resources and negotiating between the CSPs.
Cloudle (Sim K. M., 2009)	Search engine using agent-based approach is used to support service discovery between clouds, handle service negotiation and service composition.

2.2 Resource Discovery Challenges

Despite using various techniques for resource discovery as discussed above to provision planetary-scale services, intercloud resource discovery still remains a challenging yet critical task to identify and select resources to meet varying performance, cost or latency requirements of different end users and applications. If the viable solutions for resource discovery, provisioning and orchestration are not formulated in future, the vision of the intercloud will not be realized. The prominent challenges that exist include:

- (a) Resource management and coordination between CSPs, SPs and Users is required in order to optimize the cost to performance ratio. There is a need for mechanism that allows seamless end-user experience. To create benchmarks for intercloud resource discovery, real-world testing of various disparate resource types and categories, their deployment scenarios and varying user requirements is required which is not currently available.
- (b) Since there are different types of resources available ranging from physical components to abstract components, there is a strong need for appropriate naming and identification mechanisms that will result in unambiguous nature of resources which can help users to identify which resource they are requesting for easily. Heterogeneity across CSPs and use of proprietary hardware, software and middleware makes resources to be searched, re-provisioned and used very difficult.
- (c) Security issue is also one of the major concerns for the intercloud environment. Unsafe communication channels, malicious users and non-fulfilment of contracts remain major challenges for all stakeholders

including users, CSPs and SPs and thus hampering effective resource discovery.

- (d) Cloud users requesting for resources from CSPs are geographically dispersed hence, building effective location-aware resource discovery mechanisms is the need of the hour that can reduce latency which can be a major overhead in the intercloud.
- (e) Because of large scale heterogeneity within intercloud environment, creating quality interfaces and developing new management styles/interoperability mechanisms is urgently required for making intercloud resource discovery a simple process.

3. Future Perspective on Intercloud Resource Discovery

Due to the existing multiple challenges involved in intercloud resource discovery, we explore the feasibility of using a blockchain-based strategy for intercloud resource discovery that is capable of creating a P2P network of participating CSPs making use blockchain technology as a trusted ledger that maintains transactional records and ensures transparency. The idea of blockchain was first coined in 2008 by (Nakamoto, S., 2017) that provides decentralization and uses the concept of cryptography. At its core, blockchain can be thought of as a database capable of handling and dealing with transactions about various assets that can be financial, non-financial or something more abstract. Blockchain (Guardtime, 2015) is an open, distributed ledger that can record transactions happening between two parties efficiently and in a permanent and verifiable manner. The main idea is that rather than having a centralized authority, multiple distributed and disparate participants arrive at a consensus which gets recorded

in the ledger for the future reference. The proposed work makes the use of blockchain which is an emerging technology involving time stamped transactions, enables CSPs to track resources advertised by other CSPs, make optimal resource discovery and hence build trusted relationships.

Currently blockchain technology is at its early stage but is capable of changing many things and is rapidly being employed to build secure applications over the internet. It has the potential to completely revolutionize the digital world by enabling a distributed consensus where each and every online transaction including past and present, involving digital assets can be verified/validated at any given point of time in the future. The ultimate goal of blockchain is to provide anonymity, security, privacy, and transparency to all its dispersed users. Authors in (Yli-Huumo J., 2016) have conducted a systematic mapping study collecting all related and relevant research on blockchain technology and provide a complete understanding of the current research issues, challenges and future prospective regarding blockchain technology from the technical perspective. The main characteristics of blockchain can be summarized as:

- (a) Decentralization: The decentralized technology enables to store data/assets in a network that can be accessed and used over the internet allowing the owners to have a direct control enabling them to transfer the assets anywhere, anytime and to whom so ever desired. It is capable of addressing the common issues of single-point-of-failure, enhances durability and attack resistance, increases transparency and ensure authenticity.
- (b) Distributed Ledger: Blockchain being a public distributed ledger provides complete information of all the network participants and digital transactions happening between them hence, helping in recording each transaction and sharing it across the network participants. Each user on the network maintains an identical copy of the ledger and hence changes made to the ledger are visible to all network participants. Fraud protection, ease of management, ownership assurance and removal of mediator are the inherent benefits of using distributed ledger.
- (c) Safe and Reliable Ecosystem: Blockchain provides a tamper free environment for the distributed participants in the network as the network automatically checks and updates itself providing a self-reviewing system. Transactions are cryptographically secured and hence ensure integrity and security.
- (d) Mining: A computational review process done on each distributed block of data connected over the blockchain network helps in achieving consensus among the participating nodes where neither party knows or trusts each other.

3.1 Technical Concepts

The following listed technical concepts form the basis for understanding this technology and the proposed work even much better.

- (a) Node: Each participant connected over the P2P network is termed as a node or peer. It is this node which can send or receive transactions.
- (b) Block: The group of valid and confirmed transactions are combined into blocks. Each new block created contains a reference to the most recent valid block and hence a chain of blocks is maintained.
- (c) Consensus: Mechanism in which every node connected over the network agrees on the blockchain.
- (d) Submission and Transaction Validation: Nodes over the blockchain network submit transactions which are disseminated to all the other nodes. Transactions are cryptographically validated and grouped into blocks, while all the invalid transactions are ignored.

3.2 Proposed Model

Figure 3 explains a schematic representation of an indicative blockchain based intercloud resource discovery model that constitutes a P2P network of connected participants i.e. CSPs which makes use of blockchain technology for maintaining distributed shared ledger for holding transactional records. The model explains the federation of various CSPs connected over the decentralized and distributed network and involves the following steps required for intercloud resource discovery using the new idea of blockchain:

- (a) Individual CSPs connected over the network maintains an Intercloud Ledger (IC) that holds the transactions that are recorded between various nodes connected over the network.
- (b) All the transactions are time-stamped and cryptographically stored and secured in the ledger which is maintained by various nodes.
- (c) Resource requests (RR) in the form of advertisements are issued by the desiring CSPs and flooded over the P2P connected network of nodes.
- (d) Resource Advertisements (RA) in the form of unconfirmed transactions also stays in the network for a fixed amount of time and is usually associated with time-to-live (TTL) parameter. As soon as the time expires, the unconfirmed transactions are discarded and hence only the latest and current information is disseminated amongst the network participants.
- (e) The information associated with the advertisements includes the total number of resources /services offered by the CSPs, cost-value of resources, reputation-index of each CSP and QoS (quality of service) parameter.
- (f) Advertisements marked as unconfirmed transactions are flooded over the network. Verification of these unconfirmed transactions is done by some of the

CSPs also called as miners or verifiers. It is the job of these miners to verify/validate whether the advertised resources are available at the prospective CSP, the cost-value of the resources, reputation and QoS parameter of associated with each CSP. Once the verification is done and the CSPs reach a common consensus, a valid block of confirmed transactions is thus created.

- (g) The confirmed transactions in the block are cryptographically secured/stored and propagated over the P2P network of nodes.
- (h) Requesting CSPs enter into negotiation with other CSPs whose transactions are verified and validated.
- (i) Contracts are established between the corresponding CSPs based upon the reputation-index and QoS parameter of each CSP.
- (j) Final deals between the CSPs are recorded, time-stamped, cryptographically secured and propagated over the network of participants which are then grouped into a new block and updated over each CSPs individual ledger.
- (k) The new block is then linked with the previous blocks generating a chain of valid transactions and hence forming a blockchain.

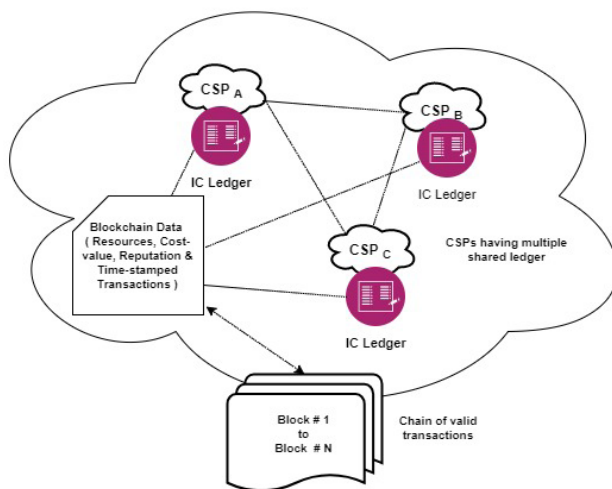


Figure 3: Schematic of indicative blockchain based resource discovery model

The proposed model showing the use of blockchain technology in intercloud resource discovery will aim at addressing the major challenges as discussed in Section 2.2 which can be listed as follows:

- a) Shared ledger amongst CSPs will help in verification of resources by individual CSPs building trust and ensuring transparency.
- b) Integrity and security can be maintained since the confirmed transactions between CSPs are cryptographically secured.
- c) Once the transactions are recorded in the shared ledger, it is difficult to modify them ensuring non-repudiation.
- d) Since no brokers are involved, all the deals are finalized by the CSPs over the network creating a cost-effective ecosystem.

Future work shall focus on using a blockchain platform Hyperledger Fabric v0.6 (Hyperledger, 2017) for real-world implementation to build intercloud resource discovery mechanism that can achieve high degree of flexibility, scalability, confidentiality and resilience amongst the P2P network of connected CSPs.

4. Conclusion

The research paper covers the main aspects of resource discovery within intercloud environment stressing mainly on the major players involved and the various existing strategies used to discover resources effectively. The paper also highlights the prominent challenges that still exist despite the various approaches and strategies proposed by some of the researchers. Since there is a need to develop a cost-effective and secured intercloud resource discovery mechanism, the paper is the first step towards use of an innovative blockchain technology within the intercloud environment. Also there are few references that mark the use of P2P approach for intercloud resource discovery. Hence, the proposed P2P model using the new idea of blockchain can result in efficient resource discovery.

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Journal of Technology Management for Growing Economies

Chitkara University, Saraswati Kendra, SCO 160-161, Sector 9-C,
Chandigarh, 160009, India

Volume -10, Issue-2

October 2019

ISSN 2456-3226

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