The Optimal Solution of Communication Resource Allocation in Distributed System Integrated on Cloud Computing

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Abstract. Cloud computing has been growing rapidly in the world over the past decade. The Studies and development of this system has met the demand of large number of users in the world. In order to share shared resources, most applications are deployed in the cloud under the control of distributed systems. The distributed system deployment on the SaaS layer responds to the maximum user access through coordination between servers. This coordinate control messages moving across servers to ensure conherence, transparency for user. However, disadvantage of coordination is that communication between servers in the cloud occupies large bandwidth; not to mention overlap of information at destination by multicast transmission. In this paper, we present optimal solution of communication resource allocation (CRA) in distributed system integrated on cloud computing based on network coding technique to ensure maximum throughput and avoid overlap of information at destination.

Keywords: Communication resource allocation · Distributed system
Cloud computing · Multicast · Network coding

1 Introduction

Cloud computing is the large system that resources allocation to users through services. The flexibility of cloud computing is a resources allocator on demand, which facilitates the maximum utilization of system resources available. For cloud computing, physical resources are used as a virtual computer combined. This provides an environment in which applications perform independently without regard to any physical resources.

Cloud computing uses dynamic resources, hence, the issue of resource allocation for this system is more complex than resource allocation in distributed systems. Virtualization that will allow for cloud computing. Virtual machine systems (VMS) combine physical resources to resource allocation for virtual machines. Characteristic of VMS is make the most of the available resources in the system and serve large number of users. In addition, VMS can deploy one or more distributed systems on it to shared resource allocation to users.

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Shared resources in the distributed system are concerned by the limited amount of resources, while the number of requests is greater than the number of requests leading to concurrency and deadlock in provisioning. The coordination between the servers in the distributed system is based on message passing mechanisms [10]. Through this mechanism, messages are controlled, routed based on structure to ensure data consistency. Studies about communications in distributed systems refer to multicast transmission mechanisms that allow a group of servers to exchange messages with each other to control shared resource allocation [4, 6, 10]. The continuous exchange of messages between servers leads to appropriate of large communication resources, thus, there should be an optimal solution in CRA.

Studies in [8, 9] point out that the disadvantage of multicast transmission is that packets that arrive at destination set can be overlapped, leading to waste of communication resources. One of the research directions to solve this solution is network coding. The goal research of network coding is to establish multicast connections and avoid overlap information at destination set. The solution for network coding technique are processing on multicast trees to achieve maximum throughput at destination set through XOR operation. This solution is built and implemented in the communication resource allocator.

Building a communication resource allocator is one of the essential conditions for control, monitoring, and resource allocation. In this paper, we present the optimal solution to CRA in distributed systems integrated on cloud computing based on network coding techniques. The main contents of the article are summarized as follows:

- Introduction a general solution CRA in distributed systems integrated in cloud computing.
- This system described the optimization algorithm CRA in VMS.
- Simulates the solution optimization of communication resources based on the network coding technology versus multicast transmission solution.

The sections of the paper are organized as follows: Sect. 2 presents the related studies, we explore, evaluate and analyze the current model to draw the advantages and disadvantages in CRA. Section 3 presents the optimal solution model and algorithms for resource allocation. Section 4 provides simulation results for evaluating a solution model from which to draw conclusions as outlined in Sect. 5.

2 Relate Works

The basic model of resource allocation in cloud computing is shown in Fig. 1, based on the specific structure of each type to classify as cloud types: private, hybrid, public and community. Services of cloud computing resource allocation to users for a variety of purposes based on demand.

In the process of resource allocation, CRA system can achieve optimum bandwidth consumption by observing real-time bandwidth consumption and making decisions about reallocation.

Studies in [13] presents an overview of resource allocation strategies in cloud computing. Discussion in the studies refers to the integration of allocation operations with utilities and services in limited resource conditions to meet user needs and cloud applications.

Studies in [5, 12] presents studies on virtualization solutions that focus on Data Center. Studies in [7, 14] present new strategies in resource allocation that studies adaptation to the inheritance used in cloud computing environments.

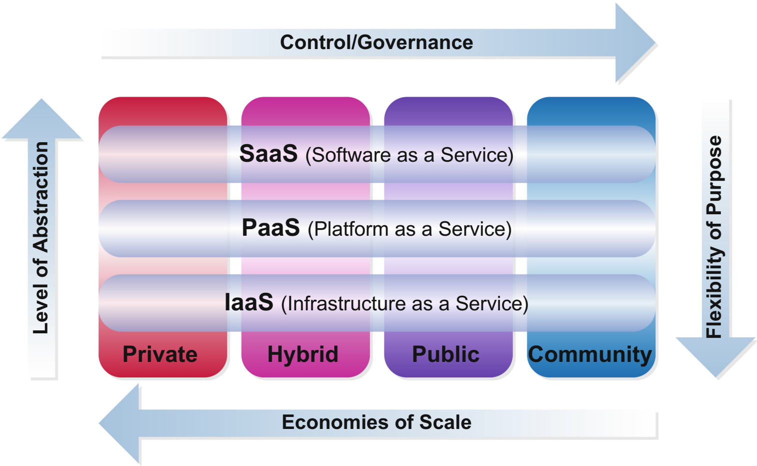

Fig. 1. The basic model of cloud computing

In addition, the approach to process of CRA on the cloud based on a network virtualization perspective. The final product of network virtualization is the virtual network. Studies in [1] presents solutions that focus on optimizing bandwidth consumption. Communication environment is virtualized by the virtual network to ensure the connection to the virtual server [3].

As shown in Fig. 2, each VM can deploy one or more distributed systems over the virtual network through a communications environment. Therefore, the optimization of communication resources in the virtual network environment should be considered.

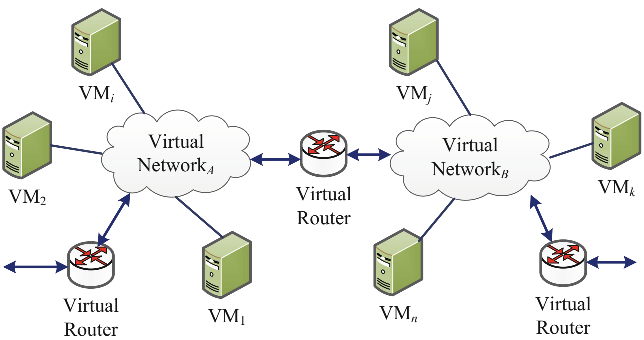

Fig. 2. Virtual distributed network

The processing that takes place inside the system is the set of virtual hosts $VM = \sum S_i\{i = 1..n\}$, where S_i is a virtual machine connected through the distributed communication system as shown in Fig. 2. Virtual machines coordinate control through message passing mechanisms to respond resources. These messages can also be considered as processes are moving in the network to request shared resources. The execution of processes depends on the communication resource allocator for routing from source to destination.

Studies in [4, 11, 13] have shown that optimal communication is based on tree-based algorithms in multicast transmissions. The disadvantage of this mechanism, however, is overlap data in communication if multiple servers provide the same information to the destination servers [8, 9]. To overcome this shortcoming, the challenge in research is offer a solution to eliminate duplicate packets. In this paper, we present a network coding technique to solve duplicate packets at the destination set.

Network coding implements concurrent data transmission over the channels to the destination of multicast transmissions by encoding packets together [2]. A single multicast session i has the communication rate between information flow and physical flow denoted tl_i to transmit packets from source to destination node.

In network coding technique, each message sent in the outcoming link of a node may have some calculation functions such as "*mixing*" other messages in incoming link of node as shown in Fig. 3 [2]. Thus, network coding technique is transmission, mixing (or encoding) and re-mixing (or re-encoding) of incoming messages at a node. As a result, messages can be republished (or decoded) at destination node. Three main advantages of network coding for communication are shown as optimal throughput, minimal power per bit, and reduced latency.

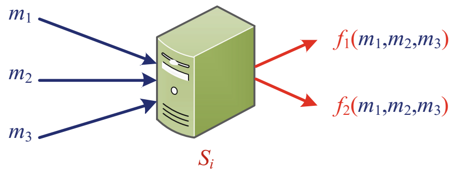

Fig. 3. Node may have some calculation functions for incoming messages

Which network coding, linear equations in the form of encoded packets with code coefficients stored in the encoded packet header, undefined variables are the actual contents of the packet. Therefore, network coding can be integrated with the software defined infrastructure (SDI) in the virtual system to increase throughput, while avoiding duplication of data at the destination node.

3 Systems Model

In order to achieve performance over multicast transmission, the solution of us is built on multicast communication rate control with network coding on the communication channels.

The description of the basic components in Fig. 4 sets out the general problem of cloud resource allocation as follows:

1. Terminals in part 5 require shared resources $YC = \sum yc_i\{i = 1..n\}$ to resource allocator of distributed system in part 2 through communication environment in part 4.
2. After receiving and processing shared resources at resource allocator of distributed system, YC send to network coding resources allocator in part 3 to processing.
3. The resource allocator in part 3 divides the YC into vectors, encoded and transmitted to servers in the distributed system through the communications resource allocator in part 2.
4. The vectors that are transmitted to destination set S_i in the distributed system for receiving, analyzing, calculating, processing and responding resources to communications resource allocator.
5. After completing the processing of shared resources, communications resource allocator to return result to terminal state of shared resource through resource allocator of distributed system.

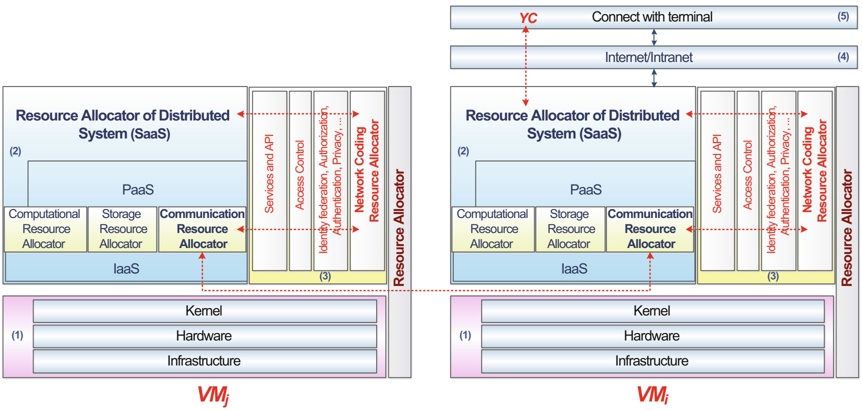

Fig. 4. The overview model of resources allocation in virtual system

This general problem sets out two basic requirements: ensuring requires of shared resources allocation and optimize communication in the system. In this paper, we focus on the optimal communication solution that ensures packet transmitted from source to destination set.

Proposition 1: Consider graph $G(U, V)$: weighted, directed, non-cyclic; denote h is mincut between source S_0 and any intermediate $S_t((t \subset T) \in U)$. Algorithm 1.1 generates a linear multicast network coding on a finite field F. Algorithm 1.1 in Fig. 5 has an execution time $O(|V| \cdot |T| \cdot h(h + |T|))$. Any finite field size $|\mathrm{F}| \geq |T|$ can be used to represent symbols sent along the edges. The results of linear codes from Algorithm 1.1 have the following characteristics:

- The source given incoming messages h.
- Node S_i needs time to execute $O\left(\min\left(\left|V_I\left(S_{ij}\right)\right|, |T|\right)\right)$ to compute messages sent along a discrete edge. The source needs time to execute $O(h)$ for each edge.
- Each intermediate can recover the original messages h in time $O(h^2)$.

Prove:

Let $start\left(S_{ij}\right)$ is a node for edge starting S_{ij}, for each S_{ij} we denote length of local encoding vector $\left|V_I\left(start\left(S_{ij}\right)\right)\right|$ according to formula (1):

$$\overrightarrow{m_{S_{ij}}} = V_I\left(start\left(S_{ij}\right)\right) \rightarrow P^{\left|V_I\left(start\left(S_{ij}\right)\right)\right|} \tag{1}$$

formula (1) is a vector that determines linear combination of messages on $V_I\left(start\left(S_{ij}\right)\right)$ generates messages on S_{ij}. $y\left(S_{ij}\right)$ was message carried edge S_{ij} according to formula (2) as follows:

$$y(S_{ij}) = \sum_{p \in V_I\left(start\left(S_{ij}\right)\right)} \overrightarrow{m_{S_{ij}}(p)} y(p) \tag{2}$$

Our task to find coefficients so that all intermediate can reconstruct original packets from messages that achieve them. We present the parallel edges $S_{12}, \ldots, S_{ih}$ from some new source $S_0^{'}$ to S_0; edges carried messages from S_0.

We can describe the efficiency of all local encoding vectors on independent edge S_{ij} of a message using global encoding vector $\overrightarrow{b\left(S_{ij}\right)} \in \mathsf{F}^h$. Length vector h is denoted by $\overrightarrow{b\left(S_{ij}\right)}$, it is linear combination of message $y\left(S_{ij}\right)$. Thus, $\overrightarrow{b\left(S_{ij}\right)} = \left[0^{i-1}, 1, 0^{h-i}\right]$ (length vector h with 1 at coordinate i) is calculated by formula (3) as follows:

$$\overrightarrow{b(S_{ij})} = \sum_{p \in V_I\left(start\left(S_{ij}\right)\right)} \overrightarrow{m_{S_{ij}}(p)} y(p), \forall S_{ij} \in V \tag{3}$$

vector $\overrightarrow{b\left(S_{ij}\right)}$ is defined because the network is non-cyclic. Using linear basic algebra, it can be considered as linear coding scheme that used for multicast transmission from source to destination only if $\forall S_Z \in D$, vector $\left\{\overrightarrow{b(p)} : p \in V_I(t)\right\}$ in span F^h. Recover the original messages can be achieved by linear equations through the variables h.

With many intermediate, our approach is to add more flow S_0–S_t. Steps of Algorithm through $S_i \in U$ in topological order. This ensures that global encoding vector of all edges to S_i are known when local encoding vectors of the edges outgoing of S_i are defined. The algorithm calculates coefficients of $\overrightarrow{m_{S_{ij}}}$ for $S_{ij} \in V_O(S_i)$, one edge at a time. There may be multiple paths to intermediate through edge S_{ij}. Let $T\left(S_{ij}\right)$ denote the intermediate set using S_{ij} in some paths p^t and

$$P(S_{ij}) = \{p^t \leftarrow (S_{ij}) : t \in T(S_{ij})\} \tag{4}$$

formula (4) is preprocessing S_{ij} in the corresponding flow path. Non-zero coefficients for $\overrightarrow{m_{S_{ij}}}$ are chosen for $P(S_{ij})$.

Line 15 in Algorithm 1.1 implemented random selection of vectors $\overrightarrow{m_{S_{ij}}}$ with support of $P(S_{ij})$ with condition $\forall t \in T(S_{ij}) : (B_t \backslash \{b(p^t \leftarrow (S_{ij}))\}) \cup \{\overrightarrow{b(S_{ij})}\}$, algorithm can execute at time $O(|V| \cdot |T| \cdot h^2)$ and return encoding message with time $O(h^2)$ at each intermediate.

Algorithm 1.1: `Linear Network Coding Determine Algorithm`

Input : Graph $G(U,V)$, source S_0, destination set D

Output: Disjoint path h from S_0 to D, vector $\overrightarrow{m_{S_{ij}}}$, intermediate $t \in T$ and weight $c \in C$, Galois field F

1 $h := \min_{d \in D} \min \{|C| : C$ is mincut from S_0 to $S_Z\}$;
2 insert new source S_0' into U;
3 insert h parallel edge $S_{12}, .., S_{ih}$ from S_0' to S_0 into U;
4 p^t denote the disjoint path h from S_0 to S_t;
5 Galois field F;
6 **foreach** i **do**
7     $\overrightarrow{b(S_i)} = [0^{i-1}, 1, 0^{h-i}]$;
8     $c_i := c_{S_{ij}}$;
9 **foreach** $t \in T$ **do**
10     $C_T := \{c_{S_{01}}, .., c_{S_{it}}\}$;
11     $B_T := \{\overrightarrow{b(S_{01})}, .., \overrightarrow{b(S_{it})}\}$;
12   **foreach** $c_t \in C_T$ **do**
13         $a_t(c_t) := \overrightarrow{b(c_t)}$;
14 **foreach** $S_i \in U \backslash \{S_0'\}$ **do**
15   **foreach** $V_O(S_{ij})$ **do**
16         $\overrightarrow{b(S_{ij})} = \sum_{p \in V_I(start(S_{ij}))} \overrightarrow{m_{S_{ij}}(p)} y(p)$;
17         $\forall t \in T(S_{ij}) : (B_t \backslash \{\overrightarrow{b(p^t \leftarrow (S_{ij}))}\}) \cup \{\overrightarrow{b(S_{ij})}\}$;
18   **foreach** $t \in T(S_{ij})$ **do**
19   advance set of edge C_T;
20   update B_T;
21   update a_t;
22   **foreach** $c_t \in C_T \backslash \{p^t \leftarrow (S_{ij})\}$ **do**
23   update a_t';
24 **return** $(h, \{\overrightarrow{m_{S_{ij}}} : S_{ij} \in V\}, \{(c_t, a_t) : t \in T\}, \text{F})$;

Fig. 5. The Linear network coding determine algorithm

Consider pair $(x_i, y_i) \in \mathrm{F}^h \times \mathrm{F}^h$ with $x_i \times y_i \neq 0$, $1 \leq i \leq n (n < |\mathrm{F}|)$. There exists a linear combination u of $x_1, x_2, \ldots, x_n$ to $u \times y_i \neq 0$, $1 \leq i \leq n$, vector u can be found in the execution time $O(|T|^2 h)$.

Thus, we have total time of execution according to formula (5):

$$O(|V|(|T| \cdot h^2 + |T|^2 h)) = O(|V| \cdot |T| \cdot h(h + |T|)) \tag{5}$$

The total execution time of the network coding compared to multicast transmission is shown in Table 1:

Table 1. Execution time of the network coding and multicast transmission

	Multicast	Network coding
Node	$O(h^2)$	$O(h)$
Edge	$O(h^2T)$	$O(h^2T)$
Network	$O(\|V\| \cdot \|T\|^2 \cdot h^4)$	$O(\|V\| \cdot \|T\| \cdot h(h + \|T\|))$

4 Simulation Results

In order to evaluate simulation of network coding, simulation requires declaration of initial variables to perform encode and decode of packets transmitted in network. Finite field value $\mathrm{F}(2^m)$ performs operations. Block variable is initialized to transmitted message in network. Length of block variable in bytes.

```
Id: 0 Payload: A0 A0 A0 A0 A0
Id: 1 Payload: A1 A1 A1 A1 A1
Id: 2 Payload: A2 A2 A2 A2 A2
Id: 3 Payload: A3 A3 A3 A3 A3
Id: 4 Payload: A4 A4 A4 A4 A4
Id: 5 Payload: A5 A5 A5 A5 A5
Id: 6 Payload: A6 A6 A6 A6 A6
Id: 7 Payload: A7 A7 A7 A7 A7
Id: 8 Payload: A8 A8 A8 A8 A8
Id: 9 Payload: A9 A9 A9 A9 A9
```

Fig. 6. Uncoded package

Figure 6 shows the input data is the number of uncoded packets, based on variable length payload and block variables, data is divided into blocks. Each packet in the packet has an ID value to identify packet reconstruction at the destination. Figure 7 shows a linear combination of blocks represented in the encoded, each encoded packet containing an encoding vector describing uncoded packets that have been merged.

```
01 00 00 00 00 00 00 00 00 00 | 00 05 00 05 00 05 00 05 00 05
00 01 00 00 00 00 00 00 00 00 | 08 05 08 05 08 05 08 05 08 05
00 00 01 00 00 00 00 00 00 00 | 04 05 04 05 04 05 04 05 04 05
00 00 00 01 00 00 00 00 00 00 | 12 05 12 05 12 05 12 05 12 05
00 00 00 00 01 00 00 00 00 00 | 02 05 02 05 02 05 02 05 02 05
00 00 00 00 00 01 00 00 00 00 | 10 05 10 05 10 05 10 05 10 05
00 00 00 00 00 00 01 00 00 00 | 06 05 06 05 06 05 06 05 06 05
00 00 00 00 00 00 00 01 00 00 | 14 05 14 05 14 05 14 05 14 05
00 00 00 00 00 00 00 00 01 00 | 01 05 01 05 01 05 01 05 01 05
00 00 00 00 00 00 00 00 00 01 | 09 05 09 05 09 05 09 05 09 05
```

Fig. 7. Linear combinations of blocks represented in the encoded

Intermediate performs linear combination of received packet with random coefficient. Intermediate generates many combinations of uncoded packets to ensure that encoded packets can be decodable with high probability. The output of the packets when transmitted in network are two matrices according to Fig. 8.

```
13 03 09 03 10 10 05 05 01 01 | 07 07 07 07 07 07 07 07 07 07
05 12 12 15 01 09 11 10 04 02 | 12 02 12 02 12 02 12 02 12 02
02 01 15 11 13 05 15 00 08 02 | 12 04 12 04 12 04 12 04 12 04
14 05 12 13 12 02 09 13 05 02 | 09 08 09 08 09 08 09 08 09 08
10 12 14 14 15 15 04 10 14 13 | 14 01 14 01 14 01 14 01 14 01
12 11 05 00 12 08 08 14 04 08 | 10 09 10 09 10 09 10 09 10 09
15 12 15 12 06 11 02 14 08 10 | 08 15 08 15 08 15 08 15 08 15
07 04 06 11 08 00 09 15 09 11 | 00 10 00 10 00 10 00 10 00 10
00 00 14 01 14 15 15 00 00 10 | 03 01 03 01 03 01 03 01 03 01
13 01 13 12 12 10 03 09 13 09 | 08 02 08 02 08 02 08 02 08 02
```

Fig. 8. The packet output in network

After reaching destination set, the decoder will decode the random linear combinations. When packets are received, the decoder executes as many encoded packets as possible to return the decoded blocks to recover original packets. The resulting decoded packets is shown in Fig. 9, which indicates that the packet ID may not be in order at the decoder during transmission from source to destination. We reorder to receive the original packet.

```
Id: 1 Payload: A1 A1 A1 A1 A1
Id: 0 Payload: A0 A0 A0 A0 A0
Id: 2 Payload: A2 A2 A2 A2 A2
Id: 3 Payload: A3 A3 A3 A3 A3
Id: 4 Payload: A4 A4 A4 A4 A4
Id: 5 Payload: A5 A5 A5 A5 A5
Id: 6 Payload: A6 A6 A6 A6 A6
Id: 7 Payload: A7 A7 A7 A7 A7
Id: 8 Payload: A8 A8 A8 A8 A8
Id: 9 Payload: A9 A9 A9 A9 A9
```

Fig. 9. The packet is decoded at destination

Through simulations packet transmitted based on network coding, packets are split, mixed and transmitted over network. At the destination set, packets are decoded and re-structured primitive to avoid packet overlap at destination with high decoded probability. Throughput at destination of three methods of transmission: unicast, multicast and network coding is shown in Fig. 10. The throughput of network coding is better than multicast transmission. This shows that network coding technique achieves optimal communication over multicast transmission.

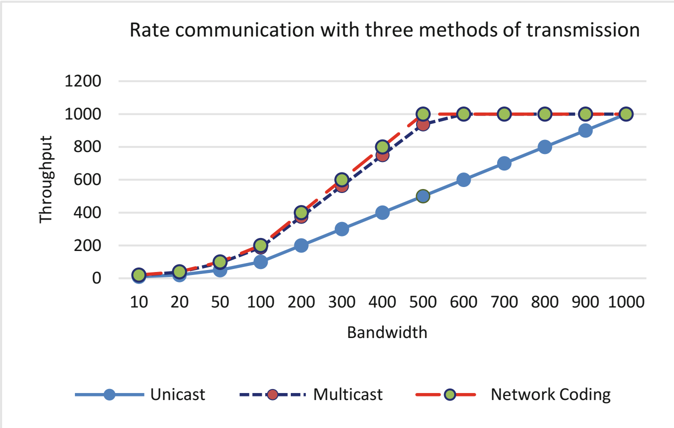

Fig. 10. Maximum throughput at the destination node with 3 methods of transmission

5 Conclusions

In this paper, we studied the optimal solution of CRA in distributed system integrated on cloud computing. We have developed an algorithm that linear network coding determine, multicast transmission combines network coding technique algorithm to ensure that the destination set receives non-overlap information and reaches maximum throughput. The solution offered is tested for accuracy and can be applied to large, complex systems. In our next research direction, the solutions are communication resources allocation with multi-source, multi-rate into multiple transmission channels. In addition, reduction of encoded, decoded complexity at intermediate and destination should also be considered.

References

1. Buyya, R., Beloglazov, A., Abawajy, J.H.: Energy-efficient management of data center resources for cloud computing: a vision, architectural elements, and open challenges. Comput. Res. Repos. **1006**(0308), 6–20 (2010)
2. Chou, P.A., Wu, Y., Jain, K.: Practical network coding. In: Allerton Conference on Communication, Control and Computing (2003)

3. Chowdhury, N.M.M.K., Boutaba, R.: Network virtualization: state of the art and research challenges. IEEE Commun. Mag. **47**(7), 20–26 (2009)
4. Erciyes, K.: Distributed Graph Algorithms for Computer Networks. Springer, Heidelberg (2013). https://doi.org/10.1007/978-1-4471-5173-9
5. Kong, X., et al.: Efficient dynamic task scheduling in virtualized data centers with fuzzy prediction. J. Netw. Comput. Appl. **34**(4), 1068–1077 (2011)
6. Kshemkalyani, A.D., Singhal, M.: Distributed Computing: Principles, Algorithms, and Systems. Cambridge University Press, Cambridge (2008)
7. Lee, Y.C., Zomaya, A.Y.: Rescheduling for reliable job completion with the support of clouds. Future Gener. Comput. Syst. **26**(8), 1192–1199 (2010)
8. Li, S.R., Yeung, R.W., Cai, N.: Linear network coding. IEEE Trans. Inf. Theory **49**(2), 371–381 (2003)
9. Li, Z., Li, B.: Network coding in undirected networks. In: Conference on Information Sciences and Systems (2004)
10. Raynal, M.: Distributed Algorithms for Message-Passing Systems. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-642-38123-2
11. Tel, G.: Introduction to Distributed Algorithms. Cambridge University Press, Cambridge (1994)
12. Urgaonkar, R., et al.: Dynamic resource allocation and power management in virtualized data centers. In: Network Operations and Management Symposium (NOMS), pp. 479–486. IEEE (2010)
13. Vinothina, V., Sridaran, R., Ganapathi, P.: A survey on resource allocation strategies in cloud computing. Int. J. Adv. Comput. Sci. Appl. **3**, 8 (2012)
14. Toby, V., Anthony, V., Robert, E.: Cloud Computing, A Practical Approach. McGraw-Hill, Inc., New York (2010)