Hindawi
Mathematical Problems in Engineering
Volume 2018, Article ID 9507823, 10 pages
https://doi.org/10.1155/2018/9507823

Research Article

The Application of Group Theory in Communication Operation Pipeline System

Jianqing Zhang,[1] Feng Xiong ,[1] and Jinsheng Kang [2]

[1]*School of Mechatronics Engineering and Automation, Shanghai University, Shanghai 200070, China*
[2]*College of Engineering, Design and Physical Sciences, Brunel University London, London UB8 3PH, UK*

Correspondence should be addressed to Feng Xiong; xfeng@mail.shu.edu.cn and Jinsheng Kang; jinsheng.kang@brunel.ac.uk

Received 27 October 2017; Accepted 22 January 2018; Published 5 March 2018

Academic Editor: Qian Zhang

To resolve the "pipeline" crisis for telecom operators, this study pioneers the application of Group theory in communication operation pipeline system. The pipeline entity group model was built for information transmission in the pipeline system to analyze operation of pipeline entities. The equations of pipeline system network traffic were established according to the flux conservation principle and matrix of pipeline network. Based on pipeline entity group model, dimensionality of the matrix was reduced. The solution scheme of the flow state transition relationship of the pipeline system is obtained, which will be very useful for the telecom operators to construct high-level mobile e-commerce application model and architecture.

1. Introduction

With the advancement of the subversive power of mobile Internet, the new generation of information technology, such as cloud computing and Internet of things, inspired the imagination of enormous participants on the industry chain and led to a new round of information revolution in recent years. Particularly, Over-the-Top (OTT) [1–3] impacts telecom industry as a main participant of the information technology reform. Over-the-Top (OTT) refers to the phenomenon that downstream third parties of mobile Internet business chain offer a variety of value-added telecom applications and services as an alternative to basic telecom service providers in the mobile Internet era.

To avoid the risk of marginalization and channelization, telecom service providers have to improve and guarantee the Quality of Service (QoS) in key business by constructing fine and delicacy management network and upgrading operation platform [4]. Quality of Service (QoS) can be often quantitatively measured by error rates, throughput, transmission delay, and so on [5, 6]. Some research have been conducted to tackle this issue; for example, smart pipeline with visual, sustainable returns was proposed as a key to the telecommunication business of efficient and safe data transmission capacity [7, 8]. Unfortunately, the proposed smart pipeline only redefined the system from two aspects of data transmission and data analysis without optimizing data traffic in distribution and transmission mechanism. Kashif et al. proposed a pipeline resource model associated with stage-level analysis to estimate the worst-case communication latency [9], and it was only for the improvement of scheduling based on real-time analysis. Markov Decision Process (MDP) model was also used to optimize the network and improve QoS in time domain dynamically [10–13], but the established model often meets "state space explosion" problems; namely, the object management problems caused by the exponential growth of object type and quantity in the computer system and computer network make Markov Decision Process (MDP) model not able to complete the calculation accurately.

Group theory has been used widely in the field of physics and chemistry as a kind of abstract mathematical tools [14, 15]. Group theory has also been used in engineering application, for example, to reduce the multiplicative computational complexity in the creation of digital holograms [16]. In the medical image processing field, the computation time is reduced considerably by exploiting symmetry presented in breast models using Group theory in order to detect breast cancer [17].

Although Group theory has been used in many fields, it has never been applied to communication network before. Based on our previous work on the three-dimensional pipeline system [18] of a telecom provider in Shanghai, this study pioneers the application of Group theory on the one-dimensional pipeline content, which is the core of service quality, namely, Quality of Service (QoS). First of all, the pipeline entity of one-dimensional pipeline system is abstracted to combine the business development needs of the Internet application of the communication industry. Secondly, the pipeline system is modeled and analyzed by Group theory. Group operation of pipeline entity state is established by discrete and symmetric transformation model. Finally, the flow state transition relationship of the pipeline system is established, and the transfer process of the system state in the group operation transformation is described. The solution scheme of the flow state transition relationship of the pipeline system is given, which will be helpful for the telecom operators to construct high-level mobile e-commerce application model and architecture.

2. Pipeline System Model Based on Group Theory

2.1. Introduction of Pipeline Entity. In the software application level in the pipeline system, pipeline entity is a platform system of business support service, including Undertaking pipeline, Service pipeline, Payment channel, Logistics pipeline, and Data pipeline. In physics and system level, pipeline entity can connect, transport, and package information. The pipeline entity can complete all kinds of connections between objects, including payment and logistics in application and physical connection nodes. One-dimensional pipe in the pipeline system has the effects of connection, support, and transmission. It is a connected entity object and transmission of information channel. When the pipeline entity constructed to scale, pipeline system will become a platform to support higher operation output.

2.2. Pipeline Entity Group and Pipeline Entity Object

2.2.1. Definition of Pipeline Entity Group. Group is a set, represented by the symbol G. A set G equipped with a binary operation $\bullet$ is said to form a group $(G, \bullet)$, if the following conditions hold:

(1) $\forall a, b \in G, a \bullet b \in G$.

(2) $a \bullet (b \bullet c) = (a \bullet b) \bullet c$.

(3) There exists an element $\in G$, such that $\forall a \in G, a \bullet e = e \bullet a = a$.

(4) $\forall a \in G$, there exists $a^{-1} \in G$, such that $a \bullet a^{-1} = a^{-1} \bullet a = e$ [19].

The definitions of pipeline group are as follows.

Definition 1. Pipeline entity group is the set of the symmetry transformation of pipeline entity.

Definition 2. The pipeline entity element is one kind of abstract operation unit which made the pipeline status transformed, acting on the communication pipeline which is estimative and logical.

In the specified information plane, a two-dimensional plane pipeline status expressed by the pipeline and its transformation is projected to the three-dimensional information space. Similarly, the pipeline status in the information space is also projected to the pipeline entity in the real space. There is a one-to-one correlation between these transformed pipeline objects in the real space and information space. Therefore, symmetric operation and translation operation of pipeline entity are EA and CP; status change operations are listed in Table 1, for example, OP, OM, PK, PB, PS, TP, TN, UM, UD, and UC. According to the definition of group, the transformations above can be judged as a part of group elements of pipeline entity group which is 12-order. Based on the two-dimensional nature, symmetry principle, and the symmetry transformation operations of 3-order components of information plane, the transformations can be classified into 6 types. These transformations can be defined as characteristic transformation matrixes and satisfy closure, distributive law, associative law, and inverse transformation of group. Characteristic transformation matrixes of group elements are listed in Table 1.

In the pipeline group G, any element G_i or G_j must satisfy that the result of calculation $G_i \bullet G_j$ is included in the group G; the symbol "$\bullet$" is one kind of specific calculation, which is similar to the placeholder of integer addition. The equation of the characteristic matrix of group element can be described as follows:

$$a_1 \{G1\} + a_2 \{G2\} + a_3 \{G3, G7, G9\} + a_4 \{G4, G8, G10\} + a_5 \{G5, G11\} + a_6 \{G6, G12\} = 0. \quad (1)$$

Only when $a_1 = a_2 = a_3 = a_4 = a_5 = a_6$ can (1) be satisfied.

Choose $G1' = \{G1\}$, $G2' = \{G2\}$, $G3' = \{G3, G7, G9\}$, $G4' = \{G4, G8, G10\}$, $G5' = \{G5, G11\}$, and $G6' = \{G6, G12\}$, so $G1', G2', G3', G4', G5', G6'$ are linearly independent in the pipeline entity group; then group G can be characterized by 6-order basic tensor; that is, other group elements and pipeline objects can be expressed with $G1', G2', G3', G4', G5', G6'$. In addition, the transformations we mentioned above can only change the state of the pipeline entities, but not be related to the change of the substance of the pipeline entity.

2.2.2. Pipeline Entity Object Status

Definition 3. Information model of pipeline objects, OM = $O\{R1, R2, B, \ldots\}$, abbreviated as O.

Pipeline object O is a vector and it is superposition state quantities of $R_1, R2, B, \ldots$, so the operation of the pipeline entity is equivalent to the treatment of the state quantities $R1, R2, B, \ldots$. In the pipeline system, the pipeline state model is shown in Figure 1.

The state of A at different times of the transformation is A'; that is, $A' = gA$, $g \in G$, where G is a pipeline entity group.