Category Theory applied to Intent Based Networking: First Steps

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Software is gaining a predominant role in modern communication networks, providing them an increased flexibility and opening new service opportunities. In this field, Intent-Based Networking (IBN) is considered to be one of the enablers of autonomous networks. This approach aims at providing a declarative interface for network operators to program the network behavior. Given the broad application spectrum, this technology doesn't have a unified description, but rather each research effort pushes for its own solution applied to a confined use case. Category theory might be a good candidate to fill this gap. In this talk, I would like to describe the first steps I've taken to apply category theory concepts to this field and to receive feedback from the ACT community. This work is based on the paper published at the Workshop on Intent Networking at Netsoft 2022 [2].

1 Extended abstract of the talk

In the last decade, modern communication networks are undergoing a drastic shift toward *softwarization*. With this process, network operators are replacing physical appliances like routers and switches with software tools deployed on off-the-shelf hardware. Thanks to this evolution, a new paradigm has emerged, the so-called "network programmability". This term refers to the ability to treat the network infrastructure and computing resources involved in service delivery as general-purpose entities that can receive instructions through Application Programming Interfaces (APIs).

By leveraging network programmability, organizations can achieve more efficient and agile network operations, streamline service delivery, and reduce operational costs.

Intent-Based Networking (IBN) is emerging as one of the most important technologies for abstracting network management operations. Through IBN, a network operator can express the desired (or intended) network state or network service without detailing the specific steps and operational procedures, and the IBN system is in charge of enforcing it, continuously monitoring its state, and verifying its consistency with the initial requirements, applying suitable corrective actions if needed. Within the Internet Research Task Force (IRTF), the Network Management Research Group (NMRG) defined an intent as "a set of operational goals (that a network should meet) and outcomes (that a network is supposed to deliver), defined in a *declarative* manner without specifying how to achieve or implement them" [3]. In short, intents are inherently a flexible and declarative way to express and compose network operations and to program network infrastructures. Unfortunately, current research efforts [1, 4, 5] push for their own solution applied to confined use cases. Given the lack of a solid foundation and the heterogeneity of use cases to be covered, I believe a flexible language like category theory could play an important role. Firstly, it could guide the definitions of robust data models for the plethora of services supported by autonomous communication networks. Then, a categorical framework can help developers in designing verifiable code, which I believe it's a topic that will gain relevance in the following years, even in telecommunica-

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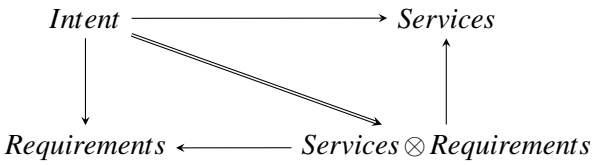
tions. Finally, a categorical description of the intent management process might highlight new mitigation methods for existing challenges (e.g., conflicting intent requests) or recognize unseen ones.

In this talk, I will present a first approach of a formal description of the IBN problem using tools from category theory, trying to highlight the correlations between these two research fields hoping it might be interesting for the ACT community.

To recap, a category containing all possible intent requests has been defined (*Intent*), with two functors mapping it to two other categories, *Services* and *Requirements*. The former represents the services that can be required by intents. The latter embeds all possible "modifiers" that an intent could ask for, such as specific Quality of Service (QoS) values to satisfy (e.g., minimum bandwidth, maximum latency, etc.) or given periods in which the intent must be enforced (e.g., "always", "all Saturdays", "only between 9 am and 5 pm").



Recalling the construction of a product in a category, given a way to map an intent to the services it is asking for and to the requirements of this request, then there exists a mapping of this intent to a couple (service, requirements), which contains all the information carried by the intent, and this mapping is unique (by universal construction).

References

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