A Perspective on Autonomous Networks from the World's First Fully Virtualized Mobile Network

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Introduction

The telecommunication industry has been keeping people around the world connected for over a century. Recently, as a result of the COVID-19 pandemic, we now communicate digitally more than ever, highlighting the pivotal role that the telecom industry plays in providing the world a platform that allows us to stay connected from the comfort of our own homes. We live in a globalized era where physical location no longer limits the flow of information. This puts a large burden of responsibility on our industry, and we must step up to this challenge and innovate, create, and deliver for today — and tomorrow.

Rakuten Mobile was born in 2018 when the Japanese government granted us spectrum, making us the fourth domestic carrier in Japan [1]. The path to success in a saturated market requires disruption in core business strategies and innovation in technology. We questioned the traditional MNO (mobile network operator) business model that heavily relies on a small number of vendors, and we put current technologies under scrutiny in order to improve and perfect an often antiquated process. Spearheaded by Mickey Mikitani, Chairman and CEO of Rakuten Group, Inc., and Tareq Amin, CTO of Rakuten Group, Inc., the world's first fully virtualized cloud-native mobile network was launched, offering a pricing plan that gave consumers a much more affordable option [2].

Looking at Today

MNOs have increasingly relied on automation to run their networks. Automation is a powerful tool that can execute predefined processes, routine tasks that any MNO must perform to ensure high performance. It can be used, for example, to create playbooks and perform repetitive tasks. As a result, automation can significantly reduce operational costs and minimize human error. Artificial Intelligence (AI) is another powerful tool that, unlike automation, has the ability to learn and infer. AI can learn to detect an anomaly in network performance or predict traffic patterns. That said, automation and AI still largely require hands-on decision-making, fine-tuning, and execution, requiring attention from human engineers. In a sense, they can be compared to a ball-point pen; it is a far superior writing tool than a fountain pen, allowing writers to jot down a message on multiple surfaces at a much faster speed.

Rakuten Mobile's success in achieving full virtualization and containerization abstracts network complexity and simplifies network management. It enables us to automate a significant portion of network deployment and operational tasks, reducing engineers' workload and CAPEX/OPEX. For example, there are countless automation scripts within our network performing routine tasks on a daily basis. Using these scripts as an automation tool, our engineering team was able to mobilize more effectively and efficiently. One example of this is our base station buildout. The use of automation has made it possible for us to rapidly deploy and on-air our base stations, allowing us to bring our target of 96% population coverage in Japan forward by about five years to summer this year. AI and automation are, indeed, useful when the task is well-defined and/or repetitive.

Gearing up for Tomorrow

To build the network of tomorrow, we cannot restrict ourselves to the technologies of today. Suppose that all aspects of our network have been automated or are being operated with AI; does it mean that we have reached the pinnacle? Absolutely not. New technologies are constantly added onto the network and the state of the network is always in flux; automation and AI alone will not be scalable. Full automation of today's network does not account for the challenges of tomorrow.

Today, telecommunication networks are responsible for providing access to ever more demanding over-the-top (OTT) content (e.g., Netflix Ultra HD streaming and Google's console-less gaming platform, Stadia, which pixel streams games in 4K). In addition, 6G is expected to present us with new applications like holographic media content [3]. This creates unprecedented pressure on the network that will continue to grow, not just in data volume but also in usage patterns. To elaborate, today's network usage is human-centric, but with the coming of factory automation and smart cities, tomorrow's network usage will be machine/software-centric, and machines never sleep. Today, we are "the pipe", facilitating flow and connectivity. With the coming of 5G and the use cases that it supports [4], telecommunication networks are extending their role, to also become a platform where services are hosted [5]. This brings us to our point: automation of the pipe is not automation of the platform.

Rakuten Mobile was founded with a forward-thinking mentality and an innovative mindset. With this mindset, we are thinking ahead, preparing our network to go above and beyond AI or automation. If AI or automation is defined as operating within well-defined parameters and/or constraints, then autonomy, in our definition, is the independence to reflect and adapt behavior beyond its well-defined parameters and/or constraints [6]. We are building a network that has the capabilities to adapt itself to unforeseen changes autonomously. Importantly, it will have the capabilities to embrace and integrate new technologies as they become available and utilize them efficiently with minimal human intervention.

Adaptation in the DNA

As the first fully virtualized network in the world, we have the privilege of being able to begin our journey of creating a truly autonomous network [7]. The next logical question is: how are we going to create a software system which possesses the ability to meaningfully adapt to the unknown within the context of a fully virtualized network?

Just as in the fields of aviation [8], materials science [9], or marine exploration [10], we look to nature for our inspiration. Nature has demonstrated how various forms of life have been able to overcome adaptation pressure and arrive at a "tailored" solution. By means of Darwinian evolution [11], species can adapt to the demands of their ever-changing environment without understanding anything about the problem itself or even being aware that there is the need to adapt. This idea of meaningful adaption to an undefined or unknown problem is extremely attractive to our ever-changing networks, where virtualization has introduced a plethora of potential software configurations and operating conditions, both within and outside of the network.

Step 1: Set Goals

Artificial evolution [12], modeled after Darwinian evolution, utilizes a fitness function that expresses the likelihood of survival of an individual. Take making pancakes as an example; the fitness function of a pancake (or a machine that makes pancakes) is

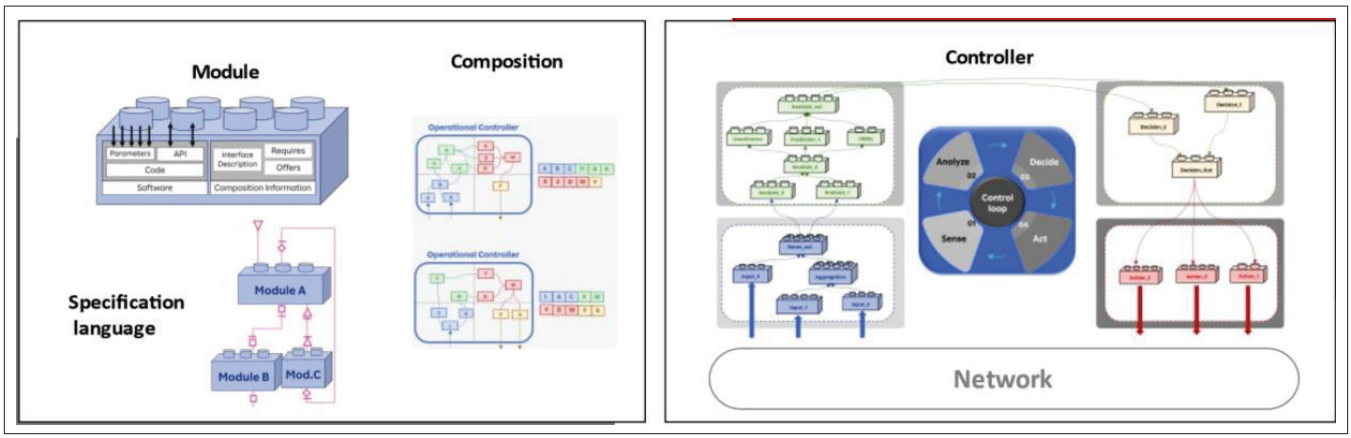

FIGURE 1. Functional building blocks within a closed-loop software controller.

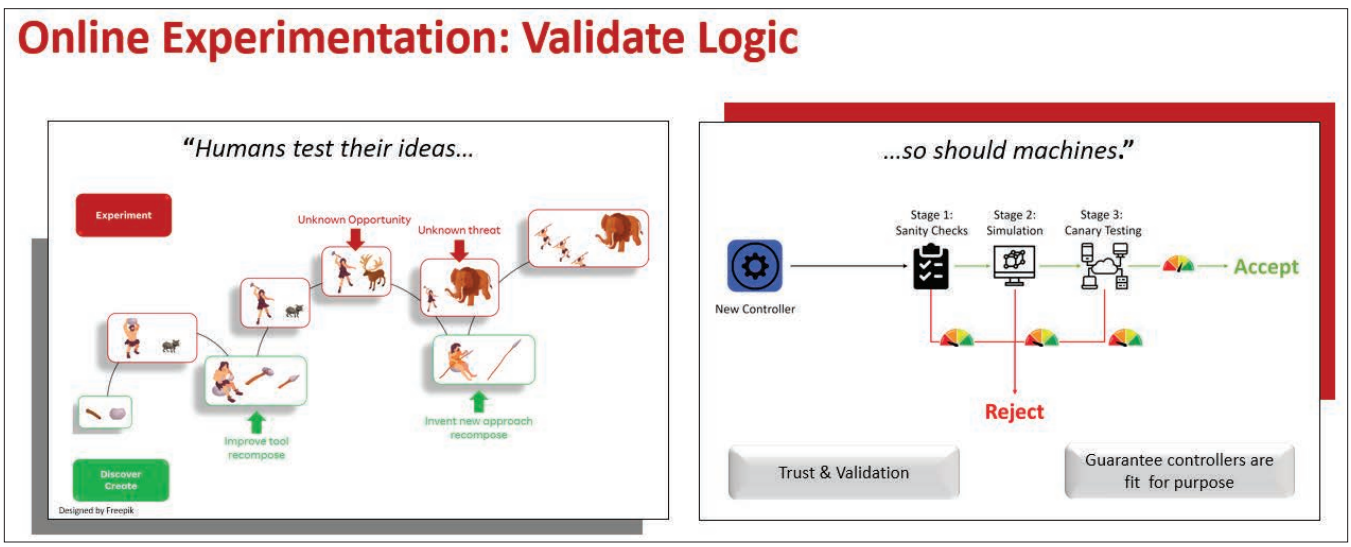

FIGURE 2. Validation of controller fit.

how the chef defines a "good" pancake. Such fitness function could be the size, shape, texture, weight, deliciousness, or cost/unit. Equally for an MNO, Key Performance Indicators (KPIs) such as Availability, Retainability and Throughput, which are commonly used as a proxy for subscriber experience, are how we define the goodness or goals of our network. Therefore, by representing our operation goals (KPIs) as fitness functions, we can apply artificial evolution in order to find a close-to-optimal solution to our adaptation and optimization challenges. These goals can be modified and extended over time to meet future requirements.

However, if a human has to explicitly tell the system how to achieve the goals, then we are still at the automation stage, where engineers must step in and conduct hands-on decision making, fine-tuning, and execution. So, how do we free ourselves from automation, which requires human intervention, to autonomy?

Step 2: Apply Logic

Our version of a truly autonomous network requires us to make algorithms and software functionality generic and express them as functional building blocks, which can be recombined within a closed-loop software controller on demand (see Fig. 1). This is the same logic used in modern software design, where existing libraries can be used interchangeably to provide replaceable functionality via compatible programmatic interfaces. We refer to this area as Apply Logic. Once we have decomposed our software into a heap of building blocks, we can let our autonomous software recombine these parts in a new way to come up with a tailored solution that fits our needs.

Step 3: Create Logic

Evolutionary algorithms are good at finding approximate solutions for almost arbitrary problems [13]; hence, the approach fits our requirements. By applying evolution to the composition and configuration of the building blocks described above into controllers and using the fitness function as a description of both the goal and measure of fitness, software can create new solutions. We refer to this area as Create Logic.

While evolutionary algorithms give us a mechanism for creativity, it can be rather computationally intensive, which may require iterations depending on the fitness landscape that does not guarantee convergence on the solution. We plan to apply meta-evolution to solve the problem of evolving search algorithms as well; however, at the moment, we must concentrate on solving the basic, ground-level problems, one step at a time.

Step 4: Validate Logic

Not all pancakes are created equal. When making a batch of pancakes, some we keep: some we throw away. The way we are building an autonomous network is no different. Figure 2 demonstrates a progressive set of static checks, simulation,

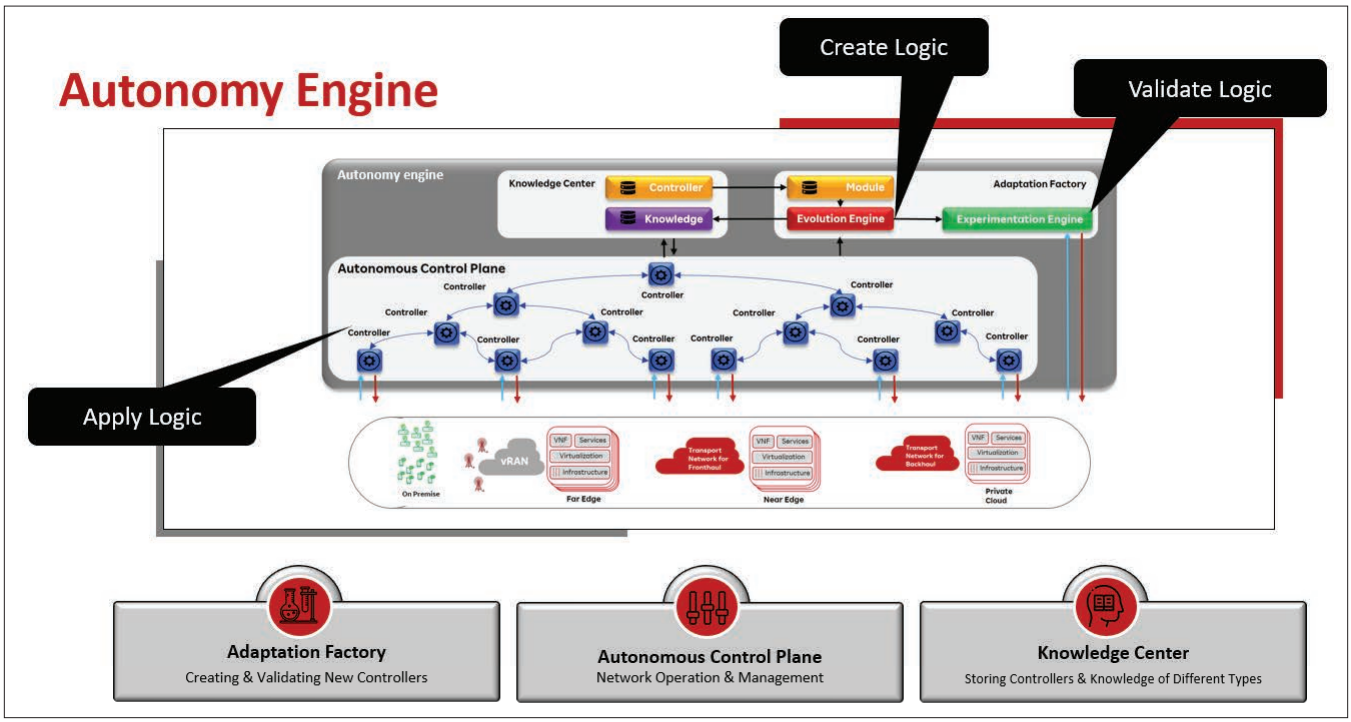

FIGURE 3. Software mechanism for adaptation.

and canary testing, which will automatically validate that controllers are fit for the purpose. We refer to this area as Validate Logic. When we combine 'create logic' with 'validate logic', it is known as online trial and error experimentation.

This is a delicate stage that is not without a caveat. We are still unable to accurately mathematically (math-magically?) model the state of the network, let alone simulate the behavior of our users in a realistic way. We can deploy trial-and-error experimentation in the real network, but this can be risky, as it may significantly impact network reliability and performance, which is unacceptable for any MNO business.

Step 5: Assemble It

In the beginning, we posed the question of "how are we going to create a software system which possesses the ability to meaningfully adapt to the unknown within the context of a fully virtualized network?" The Autonomy Engine is our answer (see Fig. 3). Building on the required virtualization, data pipelines, and automation, our Autonomy Engine combines the three high-level areas: Create Logic, Validate Logic, and Apply Logic.

We are not the only proponent of this approach. There is an ongoing momentum within the ITU-T Focus Group on Autonomous Networks (FG-AN) [14], where these key concepts are at the heart of the work. Contributors are focusing on how these concepts apply within domains of interest; for example, Validate Logic is currently being discussed in the domain of trustable AI [15]. As for Rakuten Mobile, we are interested in the exploration of an evolutionary mechanism to drive adaptation [16].

Furthermore, Rakuten Mobile is committed to combining our state-of-the-art network with state-of-the-art research. To this end, we have established research collaborations with universities under these key concepts [17], [18], [19]. We are keen to grow this ecosystem and engage with others.

Conclusion

Technology grows at an exponential rate, and so do consumer demands. We are at the intersection of humans' ability to keep up with consumers' ever-growing demands. We have to innovate technologies that can grow without human intervention, technologies that are not simply repeating tasks or self-learning but are self-evolving.

Rakuten Mobile intends to create a revolution in mobile networks by implementing one of nature's most powerful mechanisms into its network: evolution. The time has come to do things differently; the time has come for networks to evolve.

References

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