Preface

To produce this study, MIT Technology Review Insights conducted a review of telecommunications operators' network modernization experiences and plans. In addition to extensive desk research, we conducted a series of interviews with senior technology executives at network operators globally. The report, which is sponsored by Ericsson, is editorially independent. The views expressed are those of MIT Technology Review Insights.

We would like to thank the following individuals for providing their time and insights:

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**Grant Castle**, Vice President, Engineering Services and Quality Assurance, T-Mobile USA

**Eric Kuisch**, Former Chief Technology Officer, Vodafone Deutschland

**Ruben Merz**, Lead System Architect 5G and Senior Engineer, Innovation, Swisscom

**Fabio Piccini**, Director, Infrastructure and Systems, Wind Tre

**Gary Traver**, Executive, Architecture - Networks and IT, Telstra
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Telecommunications operators understand that automating network management and operations is a vital step in their networks’ modernization, and ultimately in the digital transformation of their businesses. The immediate imperative is technological: enabling network management that can efficiently address the demands being placed on it by the burgeoning growth of data, devices and new technologies. This serves a bigger imperative: enabling the business to understand and meet customer demand for services, and to scale quickly and flexibly as needed.

Automation is well underway at Tier One operators, but at many the implementation of such programs has been far from smooth. Difficult lessons have been learned. This report examines the status of network automation among large operators, their objectives and the barriers they are overcoming.

The report is based on series of in-depth interviews conducted with chief technology officers and other senior network executives at telecoms operators. The key findings are as follows:

**Early automation aims are modest, but ambitions will grow**. Expectations of opex reduction—for example, by eliminating the manual configuration of processes and reducing the time needed to fix errors—range between 30% and 50%. However, this is usually done over a
The network efficiency enabled by automation is integral to operators’ ability to manage 5G complexity and deliver end-to-end 5G services to customers.

three year time frame. Earlier gains are unrealistic, given considerable upfront costs, including from virtual network function (VNF) onboarding. Better capital efficiency is another short-term goal, while some operators see the greatest early benefit being improved network resilience.

The benefits to 5G could be made clearer. Not all operators highlight 5G in building the business case for automation. Operator executives interviewed for this report, however, agree that the network efficiency enabled by automation is integral to their ability to manage 5G complexity and deliver end-to-end 5G services to customers.

There is no one-size-fits-all automation pathway. Some operators start their automation journey with data center modernization efforts. Others focus on automating operational support systems (OSS). Wherever they start, operators logically target virtualized functions before deciding how to handle legacy systems.

People challenges are far tougher than the technology ones. Operators are making structural changes to capitalize on automation. These often involve merging or redistributing responsibilities across network and IT teams. However, retraining existing staff and trying to instill DevOps principles are by far the toughest challenges.

Although yet to be realized, hopes for open standards remain strong. Vendor integration issues have severely hampered some operators’ automation efforts. Open-source development of standardized solutions is widely supported, but it needs more commitment from all stakeholders (especially vendors) to build critical momentum.

Defining network automation

For the purposes of this report we define automation as the elimination of repeatable manual tasks and their replacement by programmed tasks automated with the use of software. In an operator’s network, examples of automated tasks include configuring servers, integrating web apps, scheduling maintenance, and adding or disconnecting services.

Orchestration is a related term, referring to the management of automated workflows across the network. The terms automation and orchestration are sometimes used interchangeably in public commentary, but the latter occurs at a wider level than the automation of individual tasks. It describes, for example, the creation of entire services through the automated configuration of several virtualized network functions.
Telecoms operators do not need to be sold on the need for network modernization. They have seen cloud-based service providers such as Google and Amazon grow into admired global companies. They have watched these companies and other over-the-top (OTT) players use their agility to deliver new types of value-added services to enterprises—something that most network operators have struggled to achieve. Adding insult to injury, these services are often delivered over operators’ own networks, with the latter seeing just a small slice of the revenue. It has long been understood in operators’ executive suites that networks overburdened with fixed physical hardware, rigid software contracts, and inflexible configuration (among other constraints) are not fit for the modern digital era.

Tier One operators, therefore, began virtualizing their networks early on in this decade. That typically involved implementing software-defined networking (SDN) and network functions virtualization (NFV) approaches. In essence, operators began moving network functionality over to software, leveraging application program interfaces (APIs) and shifting some functions to the cloud.

For many operators, these initiatives created as many problems as they solved; integrating cloud-based technologies within existing network architectures proved more difficult than initially assumed. Operators have learned that they really need to optimize their internal networks before they can reap the benefits of virtualization. This is particularly necessary in order to commercialize, at scale, the types of enterprise services they aspire to offer.

Mounting demands
While these lessons were being learned, other pressures on operator networks have continued to build. For example, traffic loads from video streaming, gaming, and other bandwidth-intensive applications have grown apace. Data traffic from Internet-of-Things (IoT) sensors is also mushrooming. Data from these services are often delivered over operators’ own networks, with the latter seeing just a small slice of the revenue. It has long been understood in operators’ executive suites that networks overburdened with fixed physical hardware, rigid software contracts, and inflexible configuration (among other constraints) are not fit for the modern digital era.

“A decent level of automation can eliminate the capex waste in operator networks that results from the inconsistent use of assets.”

Eric Kuisch, Former CTO, Vodafone Deutschland

Mobile data volumes are set to double worldwide, from 35 exabytes in 2019 to 73 exabytes by 2022
the Ericsson Mobility Report show that mobile data volumes are set to double worldwide, from 35 exabytes in 2019 to 73 exabytes by 2022.¹

Many of the emerging technologies that are rapidly gaining commercial traction will also demand that operators build much more intelligence into their networks. These trends include the growth of autonomous vehicles, applications incorporating artificial intelligence (AI), immersive environments enabled by virtual and augmented reality (AR/VR), blockchain, and edge computing.² Add to that operators’ ambitious plans for 5G service delivery, and it becomes clear that their networks must be able support the real-time, ultra-low-latency, and error-free transmission of data that most of the aforementioned technologies and applications require.

The self-operating network
Automation by itself will not inject such capabilities into operator networks. Rather, its promise is that it will transform network management. The end goal is to create a “self-operating network”—one in which all functions are completely programmable, without the need for manual configuration and troubleshooting.

Not all operators will be bold enough to voice this as the immediate objective of their current automation plans, but Tier One operators would certainly agree that they are moving in that direction. According to Eric Kuisch, former chief technology officer of Vodafone Deutschland,³ the first objective of automation is improving the network’s cost-efficiency. “A decent level of automation can eliminate the capex waste in operator networks that results from the inconsistent use of assets,” he says. Opex is, of course, the other part of the cost-efficiency promise. Opex reductions come from the gradual elimination of manual configuration and other processes as they become automated (and some rendered obsolete). They are also gained from the reduced time required to fix errors. Swisscom’s lead system architect 5G Ruben Merz says the

“Greater network efficiency through automation will bring the benefit of faster and lower-risk experimentation in the development of new services.”

Ruben Merz, Lead System Architect 5G, Senior Engineer, Innovation, Swisscom
company has derived considerable benefit from error reduction and the enhanced reliability of automated configuration. Through automation, Italian mobile operator Wind Tre aims to realize savings from sharing infrastructure between IT and network operations, said director of infrastructure and systems Fabio Piccini.

For T-Mobile USA, the overarching objectives of automation have been to improve network quality and help manage complexity, according to Grant Castle, the operator’s vice president of engineering services and quality assurance. “We’re now operating GSM, UMTS, LTE [2G, 3G, and 4G] and narrowband IoT networks, and we’re building our 5G network,” he says. “We also have a lot of service complexity, and there is a tremendous amount of device complexity out there. All of this creates a pressing need for automation.”

Similar automation objectives were described by Cahit Bollu, senior IP communications services engineer at TurkCell. The first step towards automation is cloud orchestration, which will take place this year by managing clouds for different domains and then merging them. Automation is the goal, first for upgrades to the IMS network and later for scaling features across sites and nodes. There are also staff benefits to be gained, as frequent upgrades often require night shift work that impacts other areas of productivity. “In terms of opex, we’re aiming for efficiencies of around 20%,” he adds.

“In terms of opex, we’re aiming for efficiencies of around 20%”

Cahit Bollu, Senior IP Communications Services Engineer, TurkCell

Figure 2:
Automation benefits sought by operators

- **Cost-efficiency**
  - Opex (up to 40% in 3 years)
  - Capex efficiency

- **Quality & reliability**
  - Error reduction
  - Enhanced security

- **Resilience**
  - Real-time adaptation to changes
  - Centralized management

- **Time-to-market**
  - Faster testing
  - Faster configuration

- **Manage complexity**
  - IOT, devices, data
  - 5G

Source: MIT Technology Review Insights, 2019
“We’re trying to become a digital-first company,” says Grant Castle, vice president, engineering services and quality assurance at T-Mobile USA. For network software—his area of responsibility—that means “a lot of process simplification, a lot of process automation, and a lot of system re-architecting.” It also involves a strong move toward agile development. Taken together, these efforts are helping Castle’s team accelerate prototyping and conduct almost continuous testing and validation. “We’re doing more testing per cycle and more cycles per release than we’ve ever done,” he says. “Instead of getting a release every six months, we’re getting releases every couple of weeks.”

The more-frequent testing made possible with automation and agile development, Castle and his team found, has greatly simplified validation. He says it used to take them up to three months to debug a round of software patches issued by vendors. Testing every two weeks using an agile method means that fewer errors accumulate. “We were effectively able to beta test new network software on a much more regular basis,” Castle says. “We found that there were very few issues each time it went out, and we were able to catch and fix them fairly quickly.”

Automation has also resulted in greater reliability, says Castle. About two years after launching the automation program (which began in 2015), the team noticed that it could test cases that human engineers never could. He offers a security-related example of password-testing. “How many wrong types of passwords might you want to test? How many different versions of hacking or spoofing would you like to subject your system to in order to see how secure it is? A human would stop after two or three obvious scenarios. With computers, we can send hundreds and thousands of negative test cases at a system to see if it misbehaves. So, we’re able to explore systems deeper than we’d been able to historically. That’s improved security, and improved reliability.”

T-Mobile USA: Faster testing, more releases, shorter time to market

Many of the emerging technologies that are rapidly gaining commercial traction will also demand that operators build much more intelligence into their networks.

Another important benefit is network resilience. Dynamic configuration and auto-scaling, says Kuisch, allow the network to adapt flexibly and in real-time to unexpected situations. These issues may arise from, for example, load and usage changes. “You can develop more advanced business continuity scenarios,” he says, “and make the network shockproof more than is possible with traditional, manual operations.”

Eventually, says Merz, greater network efficiency through automation will bring the benefit of faster and lower-risk experimentation in the development of new services. He cites the example of network slicing—a form of virtualization and a prominent feature of 5G networks—which allows multiple logical networks to run on top of a shared physical network infrastructure. This will enable enterprise customers to run customized services over small, virtualized sections of operator infrastructure separated solely for their use.

Such service development represents a more advanced stage of automation. Operators will ultimately be able to push its benefits out to their enterprise customers in the form of more innovative services. Along with cost-effectiveness and resilience, it represents the greater promise of automation.

Few, if any, operators claim to realize these benefits in a major way today. In the next section, we will examine how they are trying to bring this future closer.
Operators may regret not getting an earlier start on automation, but what they now need is a roadmap for tackling one area of the network at a time—finding a starting point and scaling up. Telstra has pursued what Gary Traver, executive for architecture - networks and IT, calls a “layered” approach. First, it addresses highly repetitive, high-volume processes in areas such as maintenance before beginning to “add layers of intelligence.” An example is automating network services activation. Eventually, says Traver, Telstra will add machine-learning intelligence to the network in areas such as network optimization and auto-healing. However, work remains before all the technology, processes, and policies are in place.

While network functions such as the firewall have been early targets for automation, the current focus for many Tier One operators is the onboarding of virtual network functions (VNFs). This is a complex process for operators, as launching a virtualized service typically involves procuring and then onboarding VNFs from multiple vendors. The lack of interoperability among vendor VNFs requires a considerable amount of testing and monitoring to ensure they all work together. Operators are looking to automation to reduce the complexity of VNF onboarding, as well as free up the network resources that the process requires.

Like any major technology undertaking, network automation requires a roadmap or strategy to guide it. Among other things, that roadmap should address the sequencing of automation investments and also make decisions about what should not be automated.

Bell Canada has chosen to go small rather than large, turning its central offices into small data centers that bring low-latency capabilities closer to customers.
Operators are, after all, burdened with legacy systems that will not easily be migrated to a cloud environment and are difficult to integrate with cloud-based systems. “It makes no sense at all to automate legacy,” says Traver. For Telstra, that includes any products that it intends to exit—especially as it shifts away from its copper network. “There’s a great deal of automation going on, by contrast, in how we use data to improve the customer experience.”

Is automation required for 5G?
There are differing perspectives on this question. Some analysts and vendors, for example, make the case that automation must precede or at least run in parallel with 5G network build-out. Operator executives interviewed for this report, however,

Virtualized and automated data centers for greater resilience

In late 2016, Vodafone Deutschland unveiled its new ‘Super Core’ data center in Berlin. Nearly three times as large as its standard data centers and with computing power 20 times higher (22m gigabytes a day), the complex was built with 5G and gigabit network requirements in mind. According to former CTO Eric Kuisch, it is one of four large “future-proofed” data centers being constructed across Germany, the last of which should be completed by mid-year. Rather than extending its smaller existing centers, Kuisch says, the operator decided it needed new, fully virtualized ones to meet 10-millisecond latency requirements nationwide. All four of the new centers are being automated.

Not all operators will go down this route, says Kuisch, not just because building new and expanded data centers represents a substantial investment. Automating the new data center operations (he uses the term “orchestration”) made sense for Vodafone. “This is because in the new data center concept we have only allowed for virtualized functions,” he explains. “If you modernize a data center and put in a full virtual platform in place, then you already have the building blocks for orchestration.”

The orchestration layer can use the four centers as if they were one giant platform, says Kuisch. “That’s the beauty of this approach. In the past we didn’t have much resilience across our roughly 40 data centers. But now, each of the new data centers serves as backup for one or two others. If something goes down in Frankfurt, we can set it up in Munich because it’s all software working on generic virtualized infrastructure, and it’s the same in all four locations. We can do this because all the applications are portable.”

There is no one-size-fits-all data center modernization approach. Indeed, other operators are pursuing very different data center strategies from Vodafone’s. Bell Canada, for example, has chosen to go small rather than large, turning its central offices into small data centers that bring low-latency capabilities closer to customers. But for Vodafone Deutschland, its data center expansion has provided a stepping stone and learning experience for its broader network automation efforts.

Figure 3: Global spending on NFV equipment and software, 2018-2023 (billions)

argue that the rollout of 5G radio networks and other core infrastructure is not dependent on automation elsewhere in the network.

A closer look reveals consensus, however, on the critical role that network automation will play for delivery of the end-to-end 5G services that operators keenly aspire to offer customers. According to Swisscom’s Ruben Merz, automation will help greatly when dealing with the complexity involved in managing distributed cloud infrastructure located near the edge of networks, which delivers to customers a variety of services with vastly differing resource requirements.

“‘It makes no sense at all to automate legacy.’
Gary Traver, Executive, Architecture-Networks and IT, Telstra

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**Figure 4: Operators’ deployment of NFV technology**

<table>
<thead>
<tr>
<th>Option</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>We are conducting proof-of-concept tests and lab evaluations of NFV</td>
<td>44%</td>
</tr>
<tr>
<td>We are deploying/have deployed NFV in the packet core</td>
<td>32%</td>
</tr>
<tr>
<td>We have no timetable for deploying virtual network functions</td>
<td>23%</td>
</tr>
<tr>
<td>We will start deploying virtual network functions within the next 12 months</td>
<td>21%</td>
</tr>
<tr>
<td>We are deploying/have deployed virtual customer premise equipment</td>
<td>18%</td>
</tr>
<tr>
<td>We are deploying/have deployed NFV at the mobile edge</td>
<td>18%</td>
</tr>
<tr>
<td>We are deploying/have deployed NFV in other parts of the network</td>
<td>5%</td>
</tr>
</tbody>
</table>

Compiled by MIT Technology Review Insights based on data from a TM Forum’s survey of 160 network executives from 66 companies, October 2018
“If 5G is going to change the world, we’re going to have to put millions of connected devices on our network. We’ll need automated systems that will identify devices that are bad and automatically deal with them.”

Grant Castle, VP, Engineering Services and Quality Assurance, T-Mobile USA

Automation also makes it easier to develop proofs of concept and pilots for 5G services, says Merz. “You want to be able to test the more complex types of services that 5G will enable. Automation makes it possible to do this relatively quickly before the services are put into production.”

Automation will be needed to manage other sources of 5G complexity. Device management is one, according to Grant Castle of T-Mobile. “If 5G is really going to change the world, we’re going to have to put millions of connected devices on our network, which means we will no longer be dealing with individual use case and device issues. We’ll have to deal with these things in groups, and we’ll need automated systems that will identify devices that are bad and automatically deal with them.”

In these contexts, then, the more-efficient network enabled by automation helps pave the way to operators’ 5G future. Given senior management’s hopes for the latter, operator CTOs could do no harm by including 5G in the automation business case.

The prize at stake
Which types of benefits are operators seeing from automation thus far? In the early stages, they are likely to take the form of opex and capex savings. Not surprisingly, operators are tight-lipped about the magnitude of the cost-efficiencies they are achieving with automation. AT&T is one that has been open about its targets. Its chief financial officer has stated that, once 75% of its network operations have been virtualized (expected by 2020) it will have achieved opex savings of between 40% and 50%.

Experts interviewed in this report expect that a target of between 30% and 40% opex reduction is realistic. Fabio Piccini of Wind Tre anticipates opex reductions in the range of 30-40% within three or four years. Kuisch also thinks a 40% reduction in opex is achievable from automation within three years, but only if the operator has the courage “to put complete trust in the software” and redeploy people. “This,” he says, “is a matter of faith. If you do this, reaching that 40% target is possible.”
Operators hope that the open-source development of standards for automation and virtualization software will eventually help them ease these and other difficulties. The Open Network Automation Platform (ONAP), formed in 2017 under the auspices of the Linux Foundation, is the most prominent of a number of open-standards initiatives involving operators, vendors, and developer communities. Despite membership and collaboration commitments from many of the largest such players, the platform has garnered criticism for its slow development of standardized solutions. Kuisch has high hopes for ONAP, but he acknowledges it has yet to see proven orchestration solutions emerge on the platform.

Other industry experts, meanwhile, are urging operators and vendors alike to get behind the platform and make genuine contributions to standards development. One senior executive of Orange Labs recently warned that failure to do so would jeopardize the industry’s full realization of 5G benefits.

Tougher than the technology
The people and organizational challenges that accompany automation should not be unexpected by operators, but that does not make them any easier to address. It is partly a matter of making structural changes. Telstra, says Gary Traver, seeks to eliminate silos by creating horizontal structures that span its existing network and IT teams. These had previously been entirely separate, which is the case for most operators. His role in managing networks and IT architecture “across the entire

“Everyone said they have the APIs and are compliant with the standards, but it took a long time to get them truly working together.”

Eric Kuisch, Former CTO, Vodafone Deutschland
Executives at one-fifth of operators say they have successfully deployed DevOps across their network teams, and another 31% are in the early stages of doing so.

end-to-end sphere" is a manifestation of that, he says. Similarly, mobile operator Three UK eliminated the CTO role in 2018 to distribute the office’s responsibilities across the network and IT teams. The company says the move is driven by the growing incorporation of software into its operations.12

According to Kuisch, many of the network silos are linked to different operational support systems that have evolved in house over long periods of time. These must be cleaned up, he says, in order to gain the real benefits of automation. Without such structural change, automating will only add complexity to network operations instead of reducing it.

Arguably the bigger part of the challenge is finding people to staff new or existing structures. Many Tier One operators are actively seeking to hire people capable of working with virtualization and automation technologies. According to the research firm TM Forum, this includes building in-house software teams with expertise working in open-source environments. According to the firm’s 2018 survey, by 2021, one-third of operators will employ 500 or more developers.13

Not all operators are finding it easy to hire new talent, and are opting to focus on retraining existing staff instead. Executives at AT&T, for example, found the cost of recruiting such talent at the necessary scale to be prohibitive. Instead, it launched a global retraining program with a $1 billion budget over several years. The goal is to retrain 100,000 employees (including, but not limited to, network staff) by 2020.14

“It is hard to find qualified engineers that know how to test and validate the kind of systems that we’re dealing with,” says Grant at T-Mobile. Like Swisscom and Vodafone Deutschland, the US operator is going to considerable lengths to retrain existing staff as an alternative to launching a major recruitment drive. “We’re putting a lot of effort into retraining our engineers and getting them comfortable with programming,” he says.

To create the right working environment for retrained and new staff, many operators are looking to instill the DevOps principles of agile, cross-functional working that are second nature to technology teams in cloud-native companies.15 This is the case at Wind Tre, which, according to Fabio Piccini, has started by applying DevOps to security. This is sometimes called DevSecOps, and involves introducing security early in application development. According to the TM Forum survey, executives at roughly one-fifth of operators say they have successfully deployed DevOps across their network teams. Another another 31% are in the early stages of doing so.16
Five automation lessons for network operators

This report, “Network automation: Efficiency, resilience, and the pathway to 5G” has examined the business case for automating network operations, including the benefits that can be achieved in a three- to four-year period. It also explains why, given the massive growth in traffic forecast for the next decade, automation is a critical step for future business readiness for telecom operators worldwide. From the insights of the experts who contributed, the report offers the following conclusions:

- **Face up to disruption**
  Chief technology officers may deem it risky to purposely disrupt their networks, but some structural change is necessary to gain the benefits of automation. Retention of legacy systems and silos while automating will only serve to add complexity—and cost—to network operations. And changes will be needed to integrate staff with IT backgrounds and programming skills, essential for operating the network.

- **Make a clearer link to the 5G future**
  Automation may not be necessary for 5G core networks (which already incorporate automation capabilities), but few experts doubt that it will be critical for the delivery of end-to-end 5G services. With so much riding on 5G, making the link more explicit to CEOs and CFOs can only strengthen the automation business case.

- **Keep the faith with open standards**
  Whether through ONAP or other collaborative platforms, open standards must become the norm if operators are to fully break their reliance on proprietary, single-vendor automation solutions. Beyond making fuller commitments of their own to one or another open-source platform, operators should keep up the pressure on their vendors to do the same.

- **Embrace DevOps**
  DevOps is the culture behind successful software-driven teams and businesses. Arming network staff with new skills may not be enough to help them thrive in fast-paced cloud environments. Whether or not new structures are created, learning DevOps ways of working across teams can cement the gains achieved from network automation—and much more.

- **Don’t be afraid to let go**
  Automating means trusting software to do the jobs that manual management and configuration—and the proprietary tools developed to guide them—performed. A leap of faith is required to “flip the switch” over to the automation tool. Delaying this or maintaining legacy tools for redundancy purposes are likely to negate at least some of the gains of automation.
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Endnotes
3 Kuisch was chief technology officer at Vodafone Deutschland from 2013 until December 2018.
4 See, for example, www.lightreading.com/automation/verizon-lack-of-interoperability-consistency-slow-automation/d/d-id/742362
6 www.lightreading.com/mobile/5g/bell-canada-is-binning-black-boxes-before-5g-buildout/d/d-id/738243
7 The survey data are found in Digital Transformation Tracker 3: Why Is Network Transformation So Difficult, TM Forum, October 2018, inform.tmforum.org/research-reports/digital-transformation-tracker-3-network-transformation-difficult/
10 For more information on ONAP, see https://wcm.ericsson.net/assets/local/publications/white-papers/onap_whitepaper.pdf
11 www.telecomtv.com/content/5g/orange-calls-for-all-telcos-to-rally-around-onap-and-opnfv-32508/
13 inform.tmforum.org/research-reports/digital-transformation-tracker-3-network-transformation-difficult/
16 inform.tmforum.org/research-reports/digital-transformation-tracker-3-network-transformation-difficult/

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