Software-defined vertical industries: transformation through open source

How open collaboration enables user-centered innovation, achieving faster development cycles, time to market, and increased interoperability and cost savings.

THE LINUX FOUNDATION

"When I say that innovation is being democratized, I mean that users of products and services-both firms and individual consumers are increasingly able to innovate for themselves. User-centered innovation processes offer great advantages over the manufacturer-centric innovation development systems that have been the mainstay of commerce for hundreds of years. Users that innovate can develop exactly what they want, rather than relying on manufacturers to act as their (often very imperfect) agents."

— Eric von Hippel, Democratizing Innovation

Overview

What do some of the world's largest, most regulated, complex, centuries-old industries such as banking, telecommunications, and energy have in common with rapid development, bleeding-edge innovative, creative industries such as the motion pictures industry?

They're all dependent on open source software.

That would be both a great answer and correct, but it doesn't tell the whole story. A complete answer is these industries not only depend on open source, but they're building open source into the fabric of their R&D and development models. They are all dependent on the speed of innovation that collaborating in open source enables.

As a recent McKinsey & Co. report[1] described, the "biggest differentiator" for top-quartile companies in an industry vertical was "open source adoption," where they shifted from users to contributors. The report's data shows that top-quartile company adoption of open source has three times the impact on innovation than companies in other quartiles.

Over the last 20 years, the Linux Foundation has expanded from a single project, the Linux kernel, to hundreds of distinct project communities. The "foundation-as-a-service" model developed by Linux Foundation supports communities collaborating on open source across key horizontal technology domains, such as cloud, security, blockchain, and the web.

However, many of these project communities align across vertical industry groupings, such as automotive, motion pictures, finance, telecommunications, energy, and public health initiatives. They may have started as individual efforts looking for a neutral home at the Linux Foundation. Still, over time these communities found it useful to collaborate as the organizations supporting the projects expanded their collaboration to other areas.

This paper will delve into the major vertical industry initiatives served by the Linux Foundation. We will highlight the most notable open source projects and why we believe these key industry verticals, some over 100 years old, have transformed themselves using open source software.

What is driving vertical industries to collaborate in open source?

Many vertical industries are under constant pressure to innovate. Still, there are challenges of supply chains, diverse customer requirements, regulations, and a lack of talent to do everything leadership may envision in any complex business. Some organizations choose just to do the same things they've always done over and over, but running faster or investing more than their peers. They often develop strategic frameworks built around a core competitive advantage that should give them an edge.

Some companies choose to execute their vision differently, often relying on software to re-define their processes and assets. They take the core of their business and transform it into APIs, functions, cloud assets, and use descriptive names, but are all software. Marketers started referring to this shift as "digital transformation," but at its core, companies are turning business processes and assets into software-defined assets. Once these processes and assets are software-defined, companies see the opportunities for convergence of various business functions. The trend is similar to what the world saw in the convergence of the data, voice, and other communications.

"The data shows that top-quartile company adoption of open source has three times the impact on innovation as compared with companies in other quartiles."[1]

When an organization's core strategic functions shift to a software-defined model, many of these companies find they're entirely dependent on software developers. At least one tech industry analyst refers to this realization as "The New Kingmakers."[2] This change towards software-defined infrastructure is a fundamental shift for vertical industry organizations, many of whom typically have small software development teams relative to most technology industry software vendors.

Telecommunications

LF Networking (LFN)

The telecommunications industry is 144+ years old. In the last six years, the pace of innovation has sky-rocketed, thanks to end-user driven innovation enabled by an open source evolution. Historically, telecommunications networks were proprietary, standards-based with black box, vendor-led customized equipment deployed globally. The industry also features fierce competition for wireless subscribers, significant regulation, and massive capital investments for new generations of technology valued in the billions of US dollars.

Traditionally, telecommunications providers would make generational network upgrades that involved proprietary (and expensive) switch hardware, which could not be easily modified, have their functionality modularized, or have their feature sets improved. As these providers moved into more of a software-defined model, rather than continue the use of these highly inflexible switches, they determined that the level of effort to develop their own software-defined network stack by themselves would be a massive undertaking and potentially fraught with interoperability issues if they each went at it alone.

While telecommunications providers are fiercely comp-etitive with each other, they were all trying to solve similar problems with the move from 3G to 4G, and now, 5G. Thus, the telecom firms' move towards leveraged, shared investments in collaboration on open source projects. The industry started this journey with software-defined networking and network function virtualization projects.

The Linux Foundation was the first to host an initial project to enable this transformation. When providers such as AT&T globally realized that they were solving the same "un-differentiated" problem of network automation, they joined forces, and eventually, the LF Networking foundation was created. It was the beginning of an End User Driven Innovation (in this case, Telecom Service Provider).

This ability to enable global collaboration across industry initiatives, with a focus on building open source implementations, has led to LFN becoming the de-facto open source organization. Today, over 70% of the global subscribers (as measured by the participating service providers) are built on LFN's open source projects. Contributors worldwide have contributed 78 million lines of source code to LFN projects over the last six years. Using a COCOMO valuation model,[3] those contributions would require an R&D investment value of over $7.3B to recreate.

AT&T was a leader in the open source evolution of the telecommunications industry. Leaders within the organization understood the path to software leadership, including not only consuming but collaborating through open source. Shifting the decades-old supplier-led

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...he Linux Foundation saw an opportunity and helped
...acilitate bi-lateral conversations between the technical
and business management of AT&T and China Mobile to
see if there was a path forward to working together
in open source. There was, and in early 2017, the
organizations came together to announce a merged

The LF is Changing the Fabric of Networking
"...bringing top networking vendors,
operators, service providers, and
users together."

Forbes

Cloud Native

Automation

Orchestration

Disaggregation

Software Defined
Networking

Network Functions
Virtualization

Network Functions
Virtualization

⚡ Light Reading

**Orange plans 5G +
Automation RFP**
"Requires Open Source/ONAP"

How LF Networking has changed the telecommunications industry.

vision and codebase for an Open Networking Automation Platform (ONAP) that would go on to become the telecommunications platform for operators serving 70% of the world's mobile subscribers, including among others, China Telecom, Jio, Orange, Deutsche Telekom, Türk Telekom, Verizon, Vodafone and Bell Canada.

The rate of new technology and innovation was generally every 3-6 years based on standards development cycles and individual vendor cycle product refreshes. The Linux Foundation's first telecommunications industry projects included OpenDaylight and OPNFV, which helped operators adopt technologies like Software Defined Networking (SDN), Network Function Virtualization (NFV)[6] & disaggregation to be created and deployed in some of the largest networks globally.

This collaboration was user-led in many ways, similar to Eric von Hippel's vision for user-driven innovation. However, LF Networking focused on collaboration across the global telecommunications ecosystem, improving the contributions to the open source projects and enabling a commercial ecosystem to support operators in their deployments. The technology transformation fueled by open source and enabled by LF is shown in the diagram below. The result was major open source software releases started coming out every 6-9 months, not 3-6 years.
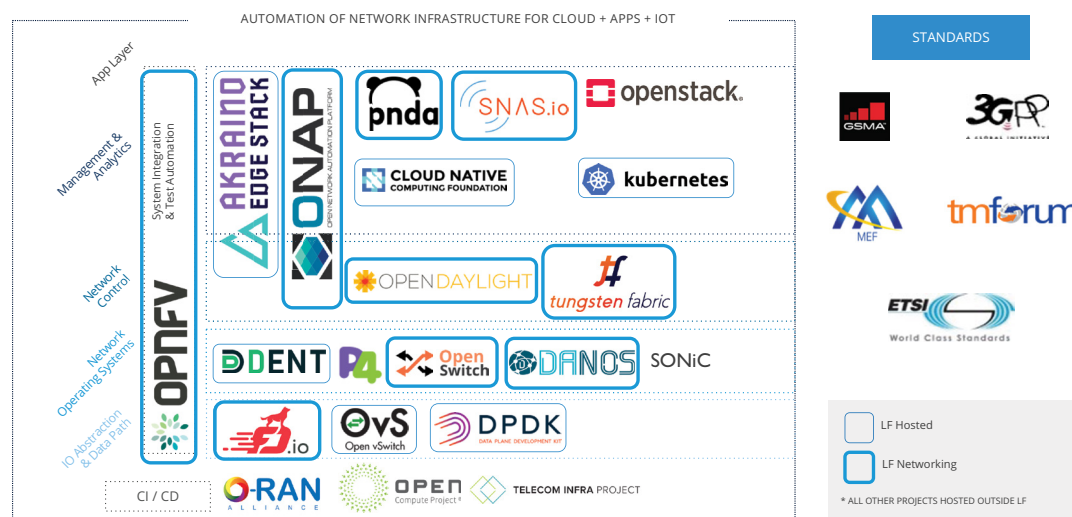
We have seen tremendous support for open source in Network Automation, 5G, AI, Edge, and RAN (Radio Access Network) in the last three years. This is truly an end user-driven innovation but with a twist. It is a global collaborative effort across telecommunications providers, their vendors, system integrators, and harmonized by implementing standards from ETSI, MEF, 3GPP, TMF, GSMA, O-RAN, etc.

Today, LFN's open source networking projects provide a full network stack of software created in open and neutral governance, enabling providers to automate networks, innovate in weeks and months versus years, while driving the cost of interoperability down.

It's interesting to look at a "stack" of open source projects that underpin a modern telecommunications provider's infrastructure. Many of these projects are hosted by LF Networking and supported by a diverse member base, enabling the industry to collaborate. These projects collaborate with standards, industry consortiums, and open hardware initiatives.

Major LFN projects include, but are not limited to:

- **FD.io:** An Open Source high-performance IO services framework for dynamic computing environments.

- **OpenDaylight:** An Open Source Software-Defined Networking (SDN) Controller with the largest ecosystem and deployment footprint.

- **OPNFV:** A project community that facilitates a common Network Function Virtualization Interface (NFVI), Continuous Integration (CI) with upstream projects, standalone testing toolsets, and a compliance and verification program for industry-wide testing and integration.

- **ONAP:** Design, creation, orchestration, monitoring, and lifecycle management open source and commercial Virtual Network Functions (VNF) and legacy networks.

A view of the LF Networking open source project and standards landscape.

- **OpenSwitch:** Brings together an ecosystem of contributors focused on a full-fledged network operating system and control plane built to run on Linux, enabling the transition to disaggregated networks.

- **PNDA:** A scalable Big Data analytics platform for networks and services.

- **Tungsten Fabric:** A software-defined network and security fabric built for rapid deployment at scale.

- **CNTT:** The Cloud Infrastructure Telco Task Force is an open initiative to get interoperability across ecosystems and standardized using open source.

- **SNAS:** Streaming Network Analytics System is a framework to collect, track, and access tens of millions of routing objects (routers, peers, prefixes) in real-time.

Networking is a key enabler for most enterprises, cloud, and service provider markets. This diagram indicates how an Open Source vision of end-to-end solutions is realized across the industry. In the future, we expect to see actual deployments roll out across the industry.

"What it's done to our cost takeout has been stunning… We are now roughly 17 quarters where the cost of [network and IT operations] has been going down year-over-year 7% to 8%. That's a stunning development."
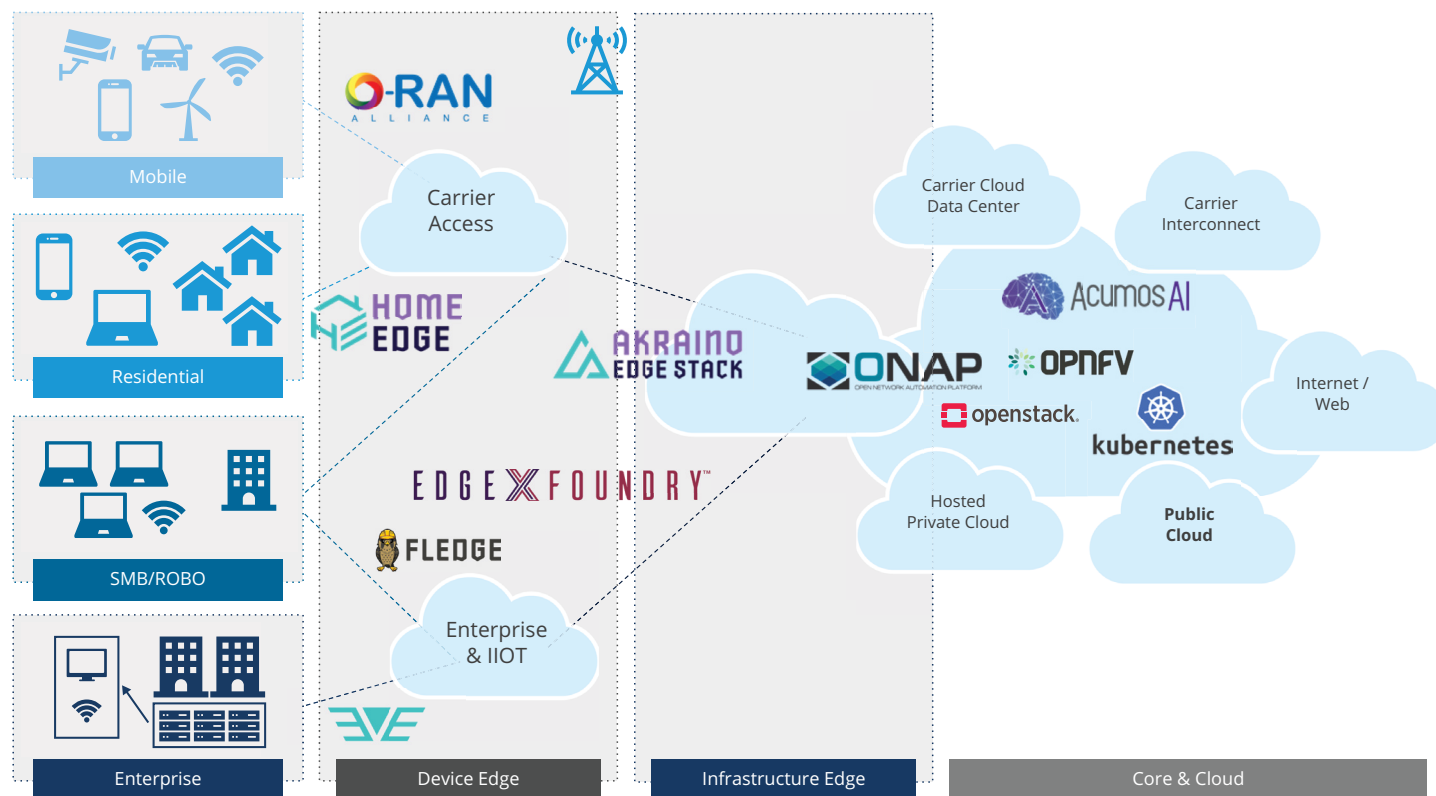
— AT&T CEO Randall Stephenson

The results of these collaborations have been amazing. AT&T CEO Randall Stephenson said that the company's efforts to virtualize its network have provided "stunning" cost savings. When talking about AT&T's transformation, Stephenson said the biggest cost AT&T has is the cost to run its network and its IT operations, and he credited the company's efforts to virtualize 75% of its core network functions through open source as paying off in big cost savings. AT&T's John Donovan "led the charge on network virtualization for AT&T and helped the telecom operator break away from the dreaded 'vendor

lock in'. Donovan has worked closely with open source groups to completely transform telco networking."[7]

Over the next three years, we will see cloud networking, edge, and access networks align on open source solutions fueling a new wave of innovation, apps, and cost savings. The community's focus is on cloud-native technologies, rapid alignment to faster, modern apps, processes, and ecosystems.

Today, some of the largest global service providers like AT&T, China Mobile, China Telecom, Verizon, Orange, DT, Vodafone, Bell, etc. run their mission-critical networks on LFN open source projects serving the majority of the global subscribers and enterprises. The entire industry has come a long way from a decade ago.

Deployment use cases for open source LFN projects in the telecommunications service provider industry
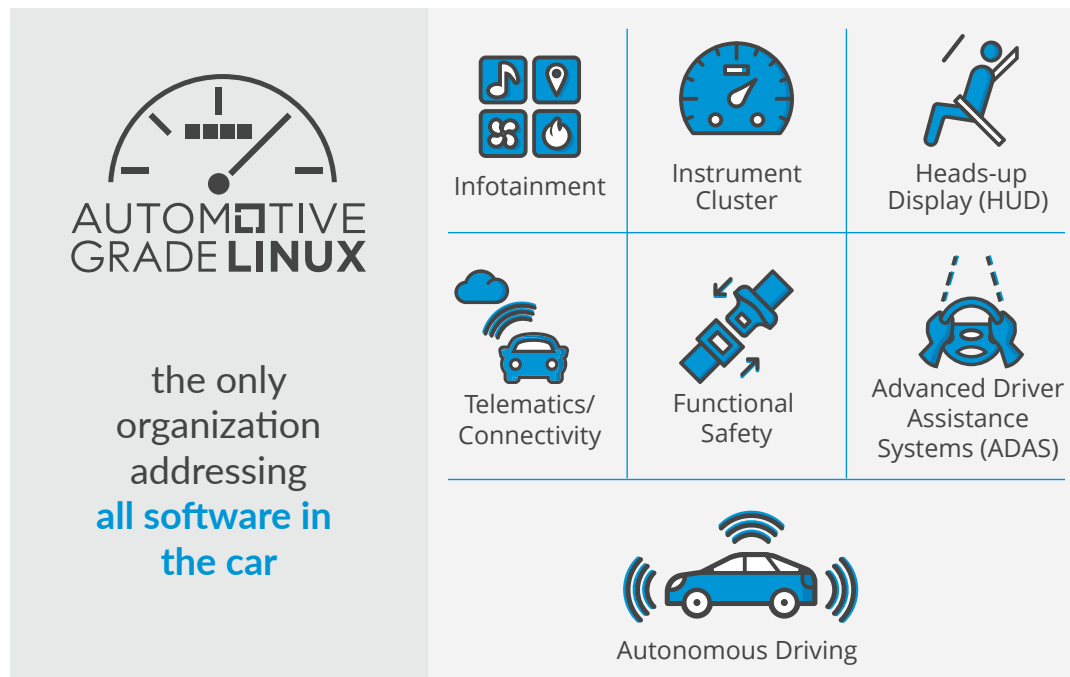
Automotive

Automotive Grade Linux (AGL)

The consumer desire for more sophisticated and feature-rich software in modern automobiles is becoming more critical than ever in the buying decision. Based on experiences with smartphones and iPads, consumers desire simpler user experience and demand to the console and in-vehicle infotainment systems with these technologies.

Head-up
Display

Technology domains within the connected automobile addressed by AGL.

model based on various component providers, innovation created a widespread fragmentation driving the ability to deliver innovation in a competitive space.

connected cars approximately 100 million of lines, which is times more than the avionics 37[9]. When you compare this to the average mobile app, which is less than it's no wonder that the product for automotive companies is so than for technology companies.

the number of systems present in an be number is functional or up to date that consumers can get in their smartphones, such as navigation and audio/video infotainment systems. Because of this ever-present it's not uncommon for an end-user to disregard although they can use their own devices for this functionality instead. The consumer experience smartphone attached to their dashboard.

gaps in functionality can be traced nature of the relationships between manufacturers and their electronic system suppliers. Historically car companies would write a specification for what a particular car model needs in terms of operating systems and then provide that specification to suppliers with desired feature sets. In turn, the supplier

provided to the manufacturer what amounts to a "black box"—a proprietary solution which, in many cases, cannot be re-used on other models of automobiles. The manufacturing process was plug-in, with little support process behind it, and very little software innovation opportunity.

Because of this supply chain process's transactional nature between the manufacturers and electronic subsystem suppliers, the in-car systems received no updates. This problem is magnified given that it is repeated across all automotive manufacturers, who all work with dozens of suppliers to produce in-car systems, creating fragmentation throughout the industry and even between their own car models. There was no re-use or re-investment by any of these automobile manufacturers long-term, resulting in an industry littered with different operating systems, many different flavors and one-offs, and huge fragmentation.

It became clear that the old supply chain did not work. Automotive companies naturally want to take ownership of the software and heavily customize it with value add, such as their UI, their own branding, their favored navigation provider, and audio/video apps. But the underlying plumbing and systems architecture needed to be reusable for a viable business case. The kernel, the middleware, application services, and the security services should also be common. This is roughly analogous to how an operating system functions for smartphone manufacturers. Google, Samsung, and Huawei have built diverse application ecosystems on top of a common Android operating system foundation.

Subaru Starlink on the 2020 Subaru Outback

That's why in 2012, the Linux Foundation worked with industry leaders like Toyota and others to launch Automotive Grade Linux (AGL). AGL was established

to build a common open source software platform that would eliminate the fragmentation plaguing the automotive industry. AGL is the only organization with a mission to address all in-vehicle software, including infotainment, instrument cluster, telematics, heads-up display, advanced driver assistance systems (ADAS), and autonomous driving.

The AGL community is reducing that fragmentation by combining the best of open source to create the AGL Unified Code Base (UCB), a single, shared, open source software platform for the entire industry. The UCB includes an operating system, middleware, and application framework and can serve as the de facto industry standard for infotainment, telematics, and instrument cluster applications. Sharing an open source platform allows for code reuse and a more efficient development process as developers and suppliers can build their solution once and deploy that same solution for multiple automakers.

Supported by eleven major automotive manufacturers, including the top three producers by worldwide volume (Volkswagen, Toyota, Daimler), AGL is deployed in production vehicles today:

- Toyota's AGL-based infotainment system is now in Toyota and Lexus vehicles globally.

- The 2020 Subaru Outback and Subaru Legacy use open source software from the AGL UCB for the Subaru Starlink infotainment platform.

- Mercedes-Benz Vans is using AGL as a foundation for a new onboard operating system for its commercial vehicles.

Motion Pictures

Academy Software Foundation (ASWF)

The Academy Software Foundation (ASWF) was developed in partnership by the Academy of Motion Picture Arts & Sciences, the home for the Academy Awards, commonly known as the Oscars. The motion picture industry was facing issues with a fragmented software infrastructure supporting the movie creation and visual effects development process. An industry survey run by the Academy found that more than 80% of the industry used open source software, particularly for animation and visual effects. The challenges were not with accepting open source software - it was getting the industry ecosystem to collaborate in the open, together. The Academy and Linux Foundation spent nearly two years working with industry stakeholders to focus on building a better, collaborative solution.

While the industry had open source projects, there was no collaboration on those projects. Studios had released software under open source models, but they never took the next step to support outside stakeholders easily contributing back. There were no common build systems outside any company's networks, so it became increasingly difficult to figure out the proper instructions to build the software. It was challenging to align dependencies and versions, leading to "versionitis" as projects required different versions of dependencies. When maintainers

left a company that "owned the project," the codebase languished. As a result, studios were reluctant to take dependence on other companies' projects, and even more unwilling to contribute their intellectual property back to another company's project. Add in a layer of one-sided contribution agreements, modifications to standard open source licenses, and other legal impediments. It was clear the status quo could not scale to meet the industry's growing needs.

The Linux Foundation and the Academy's Science and Technology Council presented the industry with an alternative path forward called the Academy Software Foundation. Announced in 2018, the ASWF provides a neutral forum to coordinate open source project efforts, as well as a common build and test infrastructure, open governance, more consistent open source licensing, and a clear path to participation for individuals and organizations wanting to advance the open source ecosystem for the motion picture industry.

The ASWF follows a typical Linux Foundation open governance structure. Each technical project operates independently and has its own decision-making model based on a "do-ocracy"; the people doing the work make the decisions. Anyone can contribute and participate in the projects, regardless of whether they are a member of ASWF. In a technical open source project, the critical value is that each contribution is weighed on the merit of that contribution adding value

to the project. Whether it's a simple bug fix, a security patch, or a new feature, the best technical solution that solves the business need will find a community that values those contributions. With no one company controlling decision making, open governance enables transparent, value-driven discussion.

Open source adoption was never the primary driver for creating ASWF—the primary mission was enabling broad collaboration in a vendor-neutral setting between studios, vendors, and other content creation organizations. Many open source projects faced stagnation due to a lack of contributors and maintainers outside of the organization that initiated a project, which would often stall development and lead to under-invested key projects.

ASWF is currently composed of six major projects, three of which are in "adopted" status, and three are in "incubation." Anyone can propose a new project, and projects are managed according to a Project Lifecycle policy that provides various requirements and provides project benefits at each stage.[10] The motion pictures industry now has a home, a process, and a governance structure to manage open source projects essential to movie production. These projects have been critical to the creation of major motion pictures enjoyed by people around the world.

- **OpenVDB:** Is an industry-standard library for manipulating sparse dynamic volumes used by visual effects studios to create realistic volumetric images such as water/liquid simulations and environmental effects like clouds and ice. Contributed by DreamWorks Animation, OpenVDB is a C++ library comprising a novel hierarchical data structure and a suite of tools for the efficient storage and manipulation of sparse

volumetric data discretized on three-dimensional grids. It has been used on films and shows, including *Frozen 2, Fantastic Beasts: The Crimes of Grindelwald, Stranger Things*, and *How to Train Your Dragon: The Hidden World.*
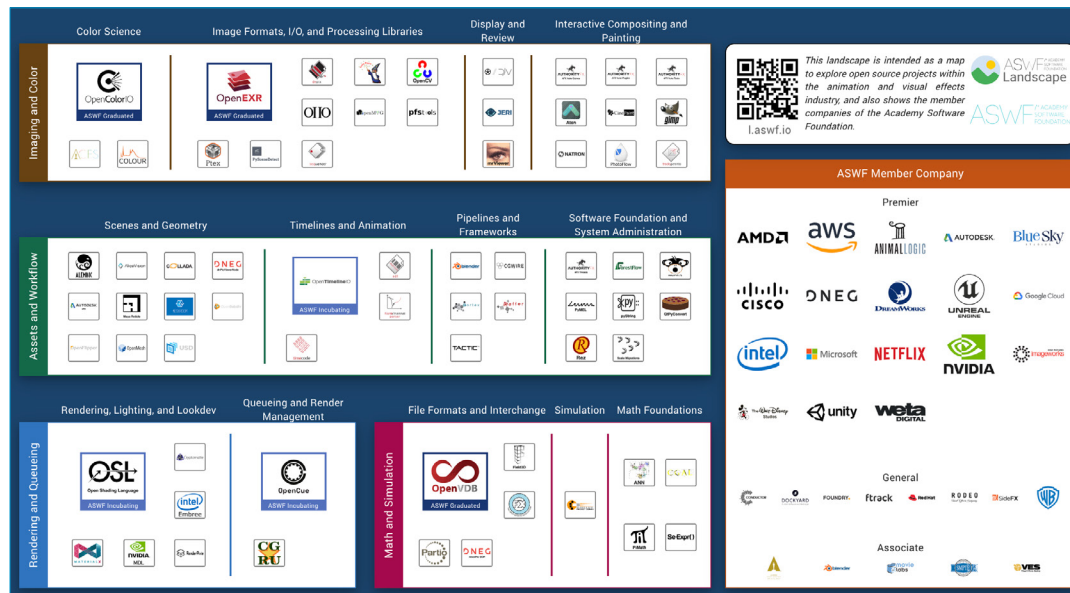

OpenVDB in use on The Croods.

- **OpenColorIO:** Is an industry standard for consistent color management across VFX and animation pipelines used on hundreds of feature film productions and touches nearly every pixel of every visual effects frame in most major motion pictures. It was contributed by Sony Pictures Imageworks, and has been used on films and shows including *Spider-Man™: Into the Spider-Verse, Spider-Man™: Homecoming, Hotel Transylvania 3, Ghostbusters, Alice in Wonderland, Cloudy with a Chance of Meatballs, Surf's Up,* and *Watchmen.*

- **OpenEXR:** One of the foundational technologies in computer imaging, OpenEXR is a standard HDR image file format for high-quality image processing and storage. It was developed by Industrial Light & Magic (ILM) in 1999 and is the first release of a major open source project by a studio. Recent films and shows include *Frozen 2, Star Wars: The Rise of Skywalker, Solo: A Star Wars Story, Star Wars: The Last Jedi, Bumblebee, Stranger Things, Avengers: End Game,* and *Fantastic Beasts: The Crimes of Grindelwald.*

- **OpenCue:** Is an open source render management system used to break down complex jobs into individual tasks. Developed by Google Cloud and Sony Pictures Imageworks, OpenCue is based on Sony's internal queuing system, Cue3, which has been developed and used in Sony production over the past 15 years to schedule and manage tens of thousands of shots over hundreds of projects. Recent films and shows include *Spider-Man™: Into the Spider-Verse, Spider-Man: Far From Home,* and *Jumanji: The Next Level.*

- **OpenTimelineIO:** Is an Open Source application programming interface and interchange format for editorial timeline information, contributed by Pixar Animation Studios. It has been used in films including *Soul, Onward, Toy Story 5, Incredibles 2,* and *Coco.*

- **Open Shading Language (OSL):** Is the de facto standard shading language for VFX and animation, developed by Sony Pictures Imageworks. It has been used on films and shows, including *Spider-Man: Far From Home, The Angry Birds Movie 2, Men in Black: International, Jumanji: The Next Level,* and *Watchmen.*

OpenColorIO, Open Shading Language, OpenCue, OpenVDB, and OpenEXR were all used on Spider-Man: Far From Home.

The ASWF has a focus on being the central hub for the foundational open source technologies that enable visual effects and animation for film and television. It has brought together key studios such as DreamWorks Animation, Sony Pictures Imageworks, Walt Disney Studios (including Pixar, LucasFilm, Industrial Light & Magic, Blue Sky Studios), Warner Bros., DNEG, Netflix, and technology vendors that support the industry. The open source ecosystem is vast, as illustrated in the ASWF Landscape, maintained by the project community.

A view of the ASWF open source project landscape

As projects were accepted into ASWF, there were immediate benefits of broader collaboration and reduced friction for contributions. Some highlights include:

- OpenVDB has had six times the number of commits in the last two years compared to the six years prior.

- OpenCue tripled its number of contributors in its first year as several new ASWF member organizations started contributing.

- OpenEXR moved from a slow, multi-year release cycle to 8 releases since joining ASWF two years ago.

- OpenColorIO tripled its contributors in 18 months as the industry collaborated to develop a significant 2.0 release.

ASWF has also become a focal point for driving new interest in software development in the motion picture industry thanks to the "Behind the Screens" interview series highlighting software developers in the industry, along with the launch of a Diversity and Inclusion working group to raise the profile of underrepresented people in these roles.

Financial

Fintech Open Source Foundation (FINOS)

FINOS (Fintech Open Source Foundation) was founded in 2018 and has quickly made strides to introduce collaborative methods that enable open source development and adoption in financial services. FINOS and the Linux Foundation have collaborated since its inception, and FINOS formally became part of the Linux Foundation in 2020. In a short time, the nonprofit has become the trusted forum for open source collaboration among major financial institutions. Only ten years ago, this was something that would have seemed unfathomable in an industry subject to intense regulation, legal requirements, complex, decades-old systems, and resistance to sharing intellectual property.

The financial services industry's traditional way of developing technology has been very "closed," similar to other highly regulated industries. While some technology has been and continues to be at the cutting edge of innovation (e.g., high-frequency trading systems), much of the software and systems do not provide a competitive advantage and are costly to develop, implement, and maintain. Systems are often rebuilt across the industry and sometimes even within the same firm. This duplication of effort signals a great opportunity for open source collaboration and its benefits through a leveraged development model across an industry.

FINOS has enabled codebase contributions from both the buy-side and sell-side firms and counts more than 30 major financial institutions, fintechs, and technology consultancies as part of its membership. FINOS members recognized early on the challenges with contributing to open source projects and invested in building out resources to assist other organizations in the industry to contribute and collaborate. These resources include guides explaining the business value of participating in open source, a license compliance handbook, and an open source readiness guide.

The results are nothing short of astounding in an industry resistant to change. In two short years, major financial institutions have increased their open source engagement, including Goldman Sachs, JP Morgan, Citi, Morgan Stanley, and Deutsche Bank. Each has contributed code to FINOS and worked alongside each other to solve common industry challenges, both large and small.

FINOS is the center for open source developers and the financial services industry to collaborate and build new technology projects that have a lasting impact on business operations. The foundation also serves as an essential, neutral body that provides appropriate governance, processes, and policies for the highly regulated financial services industry.

The financial services industry has realized many of the same benefits by adopting open source technologies as

other vertical industries. Organizations have achieved reductions in the overall total cost of ownership by sharing the development of common software components and underlying technology infrastructure through mutualization. Open source enables financial services and fintech firms to quicken their time to market for their services and product offerings and improve overall software quality.

Having a broader pool of developers working on open source software has enabled financial services companies to attract and retain talent from a larger pool. Developers like working in open source communities and participating in open source allow companies to attract top talent. Embracing open source software also allows IT stakeholders and decision-makers in financial services organizations to de-risk software investments by reducing vendor lock-in and fostering internal and external re-use of software components.

Additionally, open software and open standards have dramatically simplified workflow integration and improved interoperability between financial institutions, counterparties, and even regulators. This increases firms' ability to meet rapidly changing client and regulatory needs more quickly and seamlessly. Ultimately, FINOS seeks to create a "build once" approach to many aspects of financial technology solutions and leverages its community experts and active board-level engagement from a wide range of prominent leaders in the financial services industry.

Finally, open source collaboration has enabled financial and technology firms working in this space to learn about high-value and industry-wide business challenges that can inform and validate product and project roadmaps.

FINOS is composed of dozens of open source projects and initiatives, notably:

- **FDC3:** Launched in 2017 by OpenFin in collaboration with major industry participants, FDC3's mission is to develop specific protocols and taxonomies to advance desktop applications in financial workflows to operate in a plug and play fashion, without prior bilateral agreements.

- **Plexus:** Contributed to FINOS in 2017 by Deutsche Bank and developed in the open as part of its production Autobahn platform, Plexus defines an open standard for desktop application interoperability with a container-agnostic reference implementation.

- **Perspective:** Initially developed by JP Morgan's trading business, Perspective is an interactive Web Assembly based data streaming and visualization component for large, real-time datasets.

- **Alloy:** Set to be contributed to FINOS by Goldman Sachs later in 2020, the Alloy workbench and the underpinning Pure language offer an advanced modeling environment to explore, define, connect and integrate data into financial business processes.

- **Cloud Service Certification:** This project's overall goal is to build commonly interpreted BDD-style tests to verify cloud services' regulatory compliance. This enables building test implementations that can be used to prove the regulatory worthiness of cloud services on an ongoing basis.

- **Waltz:** Developed by Khartec Ltd and Deutsche Bank, Waltz was created to help large financial services organizations understand their application environment in a consistent, well-documented, easily digestible format to address complex enterprise architecture data organizational issues often encountered in their overall technology landscape.

- **DataHub:** Recently contributed by Citi, DataHub is a set of python libraries dedicated to producing synthetic data to be used in tests, machine learning training, statistical analysis, and other use cases.

- **Morphir:** Recently contributed by Morgan Stanley, Morphir captures an application's domain model and business logic in a technology-agnostic manner, essentially making the business knowledge available as data that can be accessed programmatically. This can enable cross-industry collaboration on business calculations, logic, rules, and more.

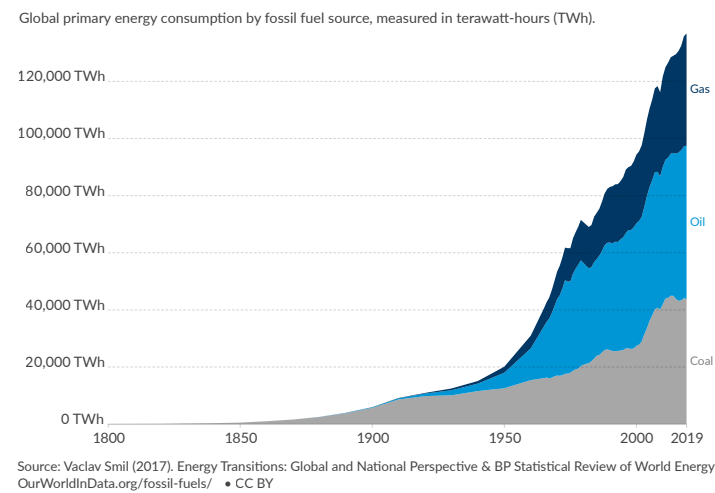A view of the FINOS open source project landscape.

Energy

LF Energy

On September 4, 1882, Thomas Edison turned on a series of interconnected generators at the Pearl Street Station in Lower Manhattan, turning on America's first electric grid. Throughout the late 1800s into the middle of the 20th century, we have experienced a great wave of innovation driven by electrons from fossil-fuel that have accelerated economic growth across every industry, initiating 150 years of prosperity.
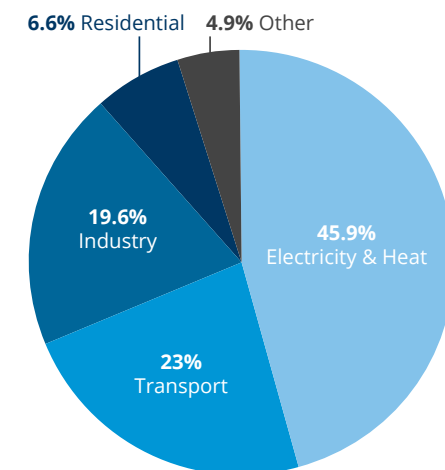
With that prosperity, the world saw a massive increase in the demand for energy production components, specifically carbon-based fuels. However, the energy distribution remained inefficient, thereby wasting valuable energy resources across the entire industry, worldwide. Compounding the climate challenges ahead, the energy industry is also responsible for nearly half of the carbon emissions generated each year.

Global energy consumption has grown exponentially in the last 20 years.

Global primary energy consumption by fossil fuel source, measured in terawatt-hours (TWh).

Source: Vaclav Smil (2017). Energy Transitions: Global and National Perspective & BP Statistical Review of World Energy
OurWorldInData.org/fossil-fuels/   • CC BY

Global energy consumption by carbon fuel source[11]

And nearly half of global carbon emissions come from the energy sector.

6.6% Residential   **4.9%** Other
19.6% Industry
45.9% Electricity & Heat
23% Transport

Sources of highest CO2 emissions[12]

While the world has vastly improved the power generation plants' capacities in overall mega wattage, the grid itself is hugely inefficient. It is estimated that approximately 60 percent of the electrons generated by power plants is lost[13] from generation to usage when you flip a switch—this is because of inefficiencies and lack of intelligent design in the distribution of electricity.[14]

Increasing demand for power in developed and developing countries will require that these inefficiencies be addressed, or the grid itself will not scale. This is compounded by the fact that government mandates in many regions of the world require a reduction in carbon footprints. In addition to creating more efficient conventional power generation plants, countries will need to integrate renewable energy sources such as solar, wind, and water turbines, moving from a centralized-style power generation model to a more decentralized one.

In the 21st century, we are faced with the unintended consequences of using carbon-intensive fuels. Today we are discovering the impact of CO2 emissions that are causing climate chaos, as evidenced by the rapid acceleration of fires, droughts, hurricanes, floods, and the melting of the polar ice caps. Real economic consequences are resulting from these changes in our environment. Countries and organizations in the energy industry are calling for urgent collective action.

Transitioning the energy systems we all depend on to move to one that is software-defined is an amazing challenge and transformation. Most industries with high competency in software have already transitioned to using open source for the core plumbing of their

systems. Once again, open source collaboration will be the only viable long term solution for the energy sector.

Today, our power grid management relies heavily on closed systems that talk to each other using standards that took years, and in some cases, decades, to get to work. But with new demands on electric grids from sources such as electric vehicles and new forms of production such as solar and wind, the challenges of integration are growing at a pace current technologies were never designed to address. Like other industries, the energy industry is shifting towards a software-defined infrastructure and digitalization of energy systems. In a software-defined model, the value of joint and shared investments, such as those created by open source projects, is much more apparent.

Early conversations between the Linux Foundation and the Réseau de Transport d'Électricité (RTE), the French power transmission authority, led to discussions about governance and shifting technology investments towards open source. Others in the industry agreed and were willing to collaborate. Out of this collaboration, LF Energy (LFE) was created to be a home for the technical projects, governance, and templates the energy industry could use to collaborate in open source openly.

The mission and vision of LF Energy are as ambitious as the scale of the problems outlined above. The LF Energy mission is to provide the neutral, collaborative open source community to build the shared digital investments that will transform the world's relationship to energy.
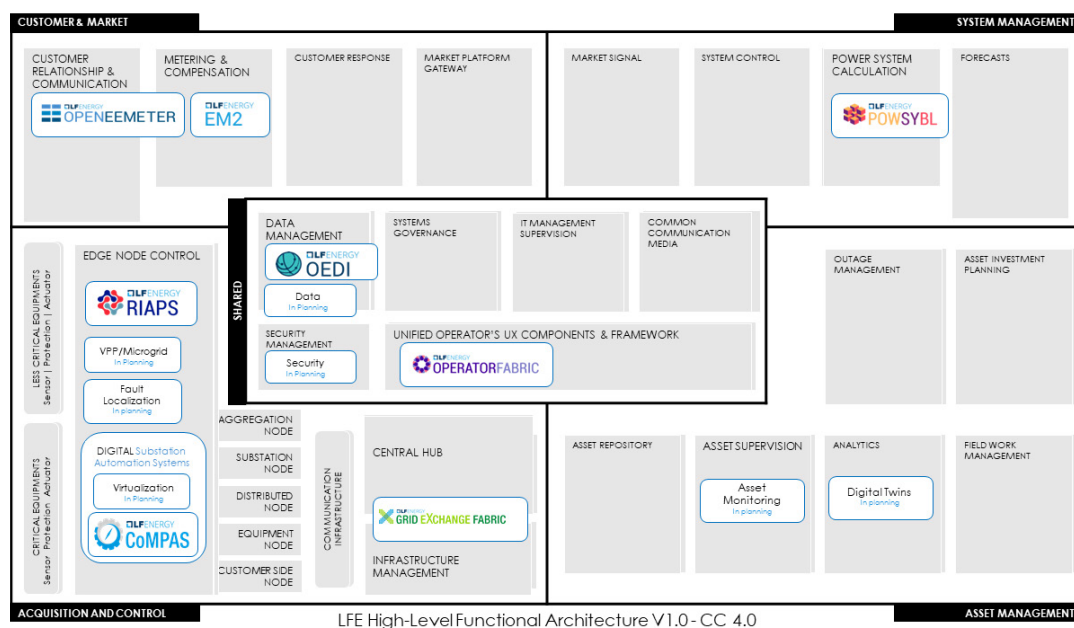
LF Energy is managed by its members, with a very active Technical Advisory Council and Governing Board made up

of representatives from Premier members—transmission system operator RTE in France and distribution system operator Alliander in the Netherlands—as well as 32 General and Associate members, including GE, OSIsoft, Recurve, TenneT, Elering, EPRI, ENTSO-E, and Vanderbilt University, among others.

LF Energy is composed of 8 projects, with several more in the formation process. Current projects include:

- **OperatorFabric:** Is a modular, extensible, industrial-strength, and field-tested platform for use in electricity, water, and other utility operations, with system visualization, workflow scheduling and alerting, and more.

- **PowSyBl:** Is the code building blocks for the simulations and analyses of power systems, for horizons from real-time operation to investment planning, with a grid data model, Java classes for extensibility, a data management system, and more.

- **RIAPS:** A Resilient Information Architecture Platform for Smart Grid (RIAPS) provides core infrastructure and services for building effective, secure, and powerful distributed Smart Grid applications. Examples include monitoring and control, data collection and analytics, energy management, microgrid control, and protection applications.

- **Grid eXchange Fabric (GXF):** Is a software platform that enables hardware monitoring and control in the public space. GXF provides several functions out of the box and includes scalability & high availability, high security, a generic design, and no vendor lock-in. GXF is currently deployed in several public use cases, including microgrids, smart metering, public lighting, and distribution automation.

- **OpenEEmeter:** Is a library and software platform for private companies, utilities, and regulators to consistently calculate changes in energy consumption for building efficiency projects and portfolios with confidence in the methods and replicability of results. It contains reference implementations of standard CalTRACK methods from EM2.

- **Energy Market Methods Consortium (EM2):** Is a consortium developing standardized methods, linked to open source code, to enable demand flexibility as a resource, supporting energy programs

LFE High-Level Functional Architecture V1.0 - CC 4.0

A high-level view of the LF Energy Functional Architecture.

and distributed energy resource (DER) markets. It is made up of industry stakeholders committed to collaboration to reduce the costs of scaling demand-side energy programs and procurements.

- **OEDI:** Provides tools, methods, and data catalogs designed and curated to promote open data exchange within the energy sector. OEDI was developed by the National Renewable Energy Laboratory (NREL) as part of the Open Energy Information (OpenEI) project, a Department of Energy initiative to accelerate and transform data related to the generation, transmission, and use of energy.

- **CoMPAS:** Is a configurator for digital substations using IEC standard 61850. CoMPAS is the first project formed from the Digital Substation Automation Systems (DSAS) working group within LF Energy.

The grid is the largest machine on the planet. The LF Energy Functional Architecture provides a harmonized overview of how the grid functions at high, medium, and low voltage.

LF Energy projects and working groups represent the first stages of defining the future grid's reference implementations.

LF Energy leverages transparent, open source development best practices and existing and emerging standards to efficiently scale, modernize, and digitally transform the power systems sector. By providing frameworks and reference architectures, LF Energy minimizes pain points such as cybersecurity, interoperability, control, automation, network function virtualization, and the digital orchestration of supply and demand management.

The digitalization of power systems facilitates a radically energy-efficient future. When every electron counts, renewable and distributed energy can enable humanity to address climate change by decarbonizing the grid. This includes widespread electrification, the transition to fossil-free transportation, and urbanization of the world's population.
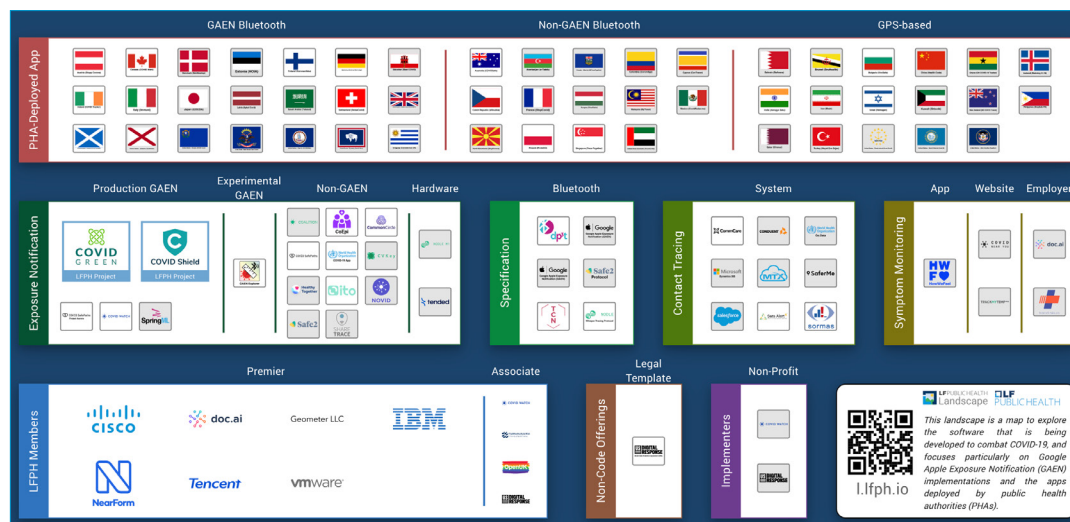
Public Health

LFPH

Public Health is the newest vertical to be addressed by the Linux Foundation, born out of the need to address the COVID-19 pandemic. Its first projects, COVID Green[15] and COVID Shield,[16] are open source implementations of exposure notification apps currently used in Ireland and Canada, using APIs implemented by Apple and Google for their respective mobile platforms.

These exposure notification apps seek to solve similar scalability and problems facing other industries described in this blog by spreading development efforts across a community of participants.

Besides hosting these two apps, LF Public Health provides various collaboration services via its Implementer's Forum[17] to enable countries and regional governments to decide on and implement best practices. Notable topics for discussion within the forum among participants are radio frequency signal strength, user signup flows, privacy, and legal documentation. Whether public health authorities use one of the LFPH-hosted apps or a different option, they benefit from access to a neutral forum for collaboration.

LFPH represents the future of where open source industry collaboration can go to address global pandemics and other societal issues.

A view of the LFPH open source project landscape

A sample COVID Shield exposure notification.

"The user-centered innovation process … is in sharp contrast to the traditional model, in which products and services are developed by manufacturers in a closed way, the manufacturers using patents, copyrights, and other protections to prevent imitators from free riding on their innovation investments. In this traditional model, a user's only role is to have needs, which manufacturers then identify and fill by designing and producing new products."

— Eric von Hippel, Democratizing Innovation

Conclusion

While all of these vertical industries have unique open source projects and communities, they also share a common thread. All of them realized that open collaboration presents opportunities reducing costs, time to market, increasing quality, and opening new areas of competition. The ability to achieve these results on a collective basis pushes innovation forward across respective industries.

The top quartile industry competitors figured out years ago that they also needed to be the top quartile in software innovation, so they studied the world's top software development companies. They discovered that the software leaders had been openly collaborating for a decade or more building software plumbing and infrastructure. They were licensing these

assets they developed in open source so they would be openly available to anyone. On reflection, many came to understand that their individual ownership of intellectual property for parts of their software stack that customers didn't care about was limiting in terms of business opportunity and expensive in terms of development and maintenance. To accelerate adoption, openly working together on common plumbing could present more opportunities for business growth.

The case studies of successful patterns were right in front of them. They discovered projects such as Linux, Apache web server, and Eclipse, all enabled software innovators and users to much more rapidly build higher-value software their customers were demanding. The open source model of collaboration on the founda-

tional software made these companies faster innovators and was followed with lower individual investments as the development costs were shared across the organizations working in the project community.

Then the realization hits: instead of working for years on a standard that everyone could go off and invest in implementing their own way, these open source projects are openly building a shared industry implementation that effectively becomes a neutral,

de-facto standard everyone can build competitive offerings and solutions upon.

What happened next is nothing short of amazing to have watched as these industries transformed how they build infrastructure for their industry from individual competitive firms building everything for themselves to communities of competitive firms collaborating in the open.

1   https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/developer-velocity-how-software-excellence-fuels-business-performance#

2   https://www.oreilly.com/library/view/the-new-kingmakers/9781449368036/

3   https://en.wikipedia.org/wiki/COCOMO

4   https://www.att.com/Common/about_us/pdf/AT&T%20Domain%202.0%20Vision%20White%20Paper.pdf

5   https://about.att.com/innovationblog/linux_foundation

6   https://www.sdxcentral.com/networking/nfv/definitions/whats-network-functions-virtualization-nfv/

7   https://www.fiercetelecom.com/telecom/at-t-s-stephenson-says-virtualization-provides-stunning-cost-savings

8   http://www.visualcapitalist.com/millions-lines-of-code/

9   https://www.digitaltrends.com/cars/the-ford-gt-uses-more-lines-of-code-than-a-boeing-787/

10   https://github.com/AcademySoftwareFoundation/tac/blob/master/process/lifecycle.md

11   https://images.app.goo.gl/sJvFaUzVg2Yx5Nen8

12   https://images.app.goo.gl/Lj8eBzY2zNz73FeW8

13   http://insideenergy.org/2015/11/06/lost-in-transmission-how-much-electricity-disappears-between-a-power-plant-and-your-plug/

14   https://3dfs.com/articles/wasted-electricity-vs-lost-electricity-in-the-u-s-electrical-grid/12/2015

15   https://github.com/covidgreen/covid-green-app

16   https://www.covidshield.app/

17   https://implementers.lfph.io/

THE LINUX FOUNDATION

The Linux Foundation promotes, protects and standardizes Linux by providing unified resources and services needed for open source to successfully compete with closed platforms.

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