SERVICE MESH HANDBOOK

tetrate

www.tetrate.io

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Executive Summary

Service mesh is a relatively new architecture for application development and delivery. Service mesh has emerged in response to the challenges of digital transformation and application modernization, as it offers the consistent observability, connectivity, security, and resilience capabilities that modern microservices applications require.

In the enterprise, service mesh plays a critical role in the areas of application modernization and cloud migration. It's a necessary tool for organizations that need a zero trust security posture, are managing multi-platform or multi-cloud environments, or a combination of the above.

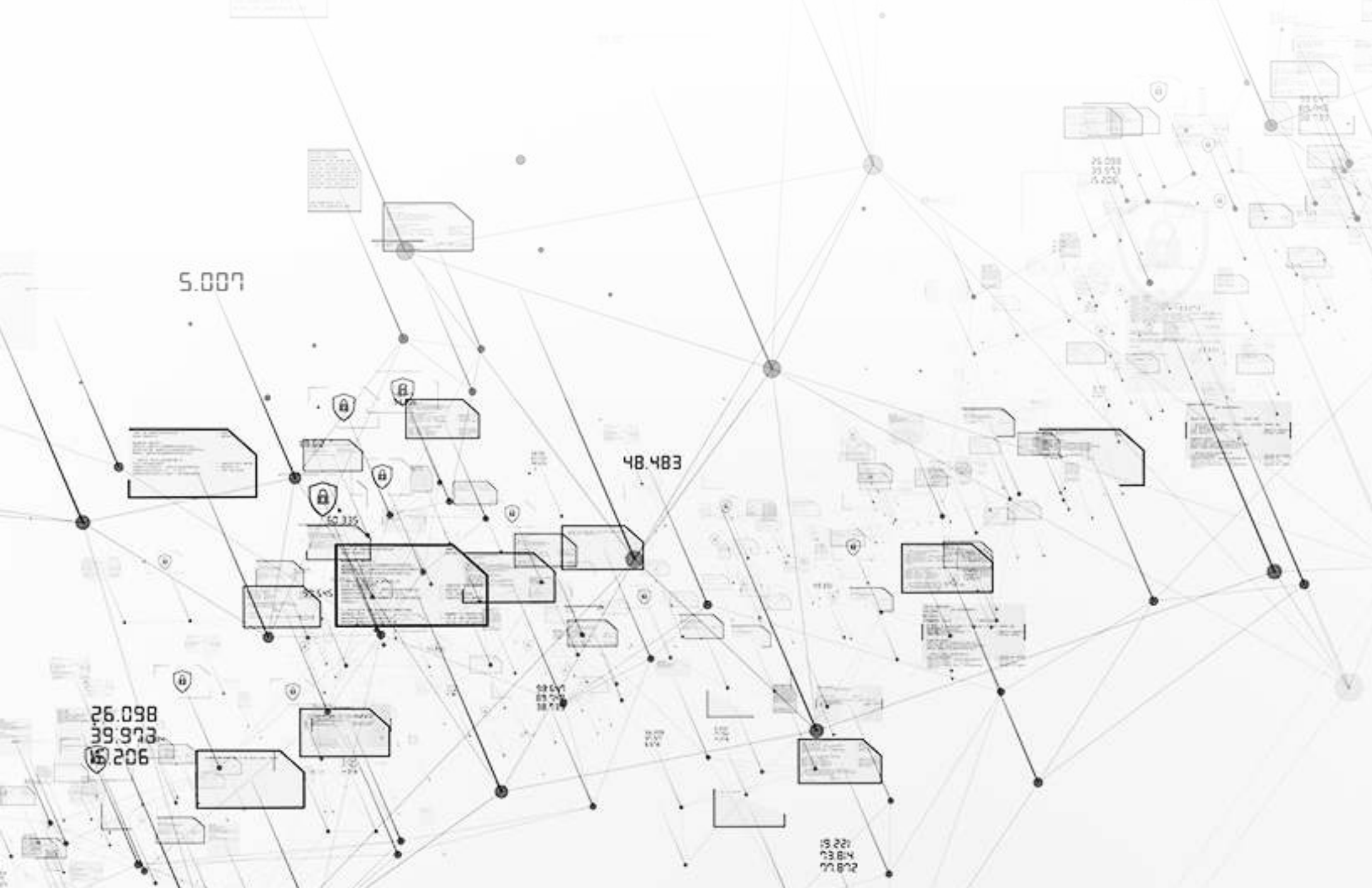
The frequently heard term zero trust architecture (ZTA), when applied to microservices applications, most often refers to service mesh-based architectures. Applications using a zero trust architecture are developed and managed in production using the DevSecOps approach, which adds security concerns to the well-known DevOps paradigm.

An enterprise service mesh extends the benefits of a service mesh to every workload, regardless of the application architecture or underlying compute platform or environment, with added operational and security benefits such as seamless traffic shifting, multitenancy, and support for failovers across multiple clusters and even multiple clouds.

This paper offers an overview of what a service mesh is, what it's for, and its major benefits to the enterprise.

Chapter 1

Service Mesh Background and Introduction



Background and Introduction

Rapid change is a constant in technology, but you might be forgiven for thinking that, at the moment, change is even more rapid than normal. There is a fairly predictable cycle of creative destruction in enterprise-scale information technology, but the last few years have been a bit different.

Since at least the microprocessor revolution,which began in the 1970s, there has tended to be a single technology shift in progress, at any given time, that has an outsized influence on technology change. In the 1970s and '80s, that change driver was the phenomenal acceleration of microprocessor power (which continues). In the 1990s and 2000s, it was the accelerating global adoption of the Internet and the World Wide Web, and the mass scramble of businesses to reach "Internet scale."

Our current moment is a bit different, though. We are in the middle of a large shift in how most things get done, powered by four transformations:

The movement from paper and people to digital assets and processes, which was only accelerated by the global pandemic when it arrived in 2020

Shifting infrastructure, from servers in organizationally-owned data centers to public cloud providers

Shifting architecture, from monoliths to microservices

Shifting processes, from long waterfall development and delivery cycles to agile approaches

Below, we'll describe how strong the forces of change are - and how most organizations are suffering various problems as a result of these shifts. We will then introduce service mesh as a viable solution to many of these issues.

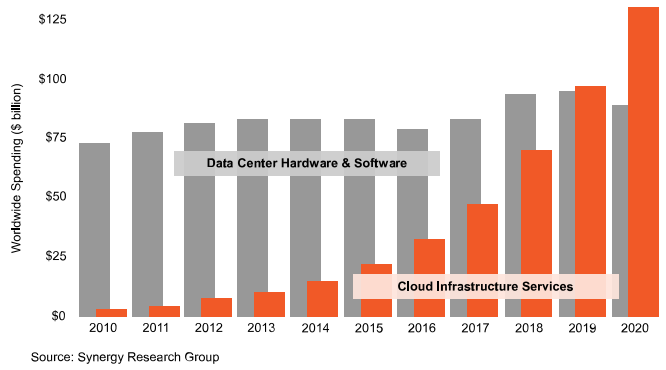
Accelerating Cloud Adoption

Cloud & Hybrid Cloud

Gains

- Reducing need to provision infrastructure
- Managed services
- OPEX vs CAPEX

Enterprise Spending on Cloud and Data Centers



Challenges

- Consistent security policies
- Lack of needed skills in IT
- Ease of application troubleshooting

In 2019, spending on cloud infrastructure services first eclipsed enterprise spending on data center hardware and software (Synergy, 2021). This marks the inevitable tipping point where, after a decade of accelerating growth, the cloud's future is now.

The allure of cloud computing for enterprises is well understood, after having been on the leading edge of the hype cycle for a decade and a half:

1. It's dead easy to provision infrastructure
2. Managed cloud services make huge swaths of technical expertise, effort, and organizational pain someone else's problem
3. The cloud enables a consumption-driven pricing model, reducing the need for up-front planning, budgeting, and spending
4. New and advanced technologies can be tried and adopted much faster, and at a much lower cost of entry, enhancing agility
5. Staffing needs for a wide range of technical specialties, many very hard to hire for, are reduced or eliminated

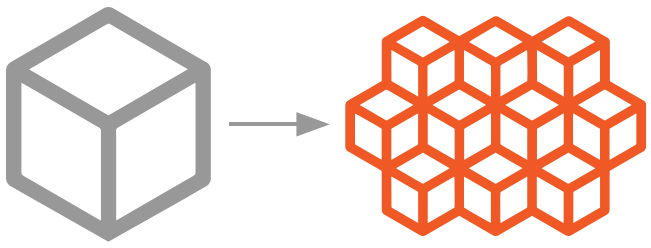
Of course, no cloud is all silver lining. There are downsides to significant cloud adoption, many of which only become apparent a fair way into the journey. Chief among the gripes large cloud adopters have is the cost. The flip side of “pay as you go” is, “as you go, you pay.”

While it may be easier to have other people provision infrastructure and manage it for you, it's not cheap. It's also harder to see the big picture when applications are spread across many different environments. This can make troubleshooting more difficult. In addition, it's harder to implement, enforce, and audit consistent security policies across a combination of cloud, or clouds, and company-owned data centers.

At the same time that cloud adoption accelerates, the data center is not going away anytime soon. While on-premises spending may be flat, at ~$80-90B/year (Synergy, 2021), it's still a massive investment in traditional digital assets. While organizations race to the cloud, they'll be managing their existing application stock alongside their shiny new cloud applications for many years to come.

Modernization Momentum Continues

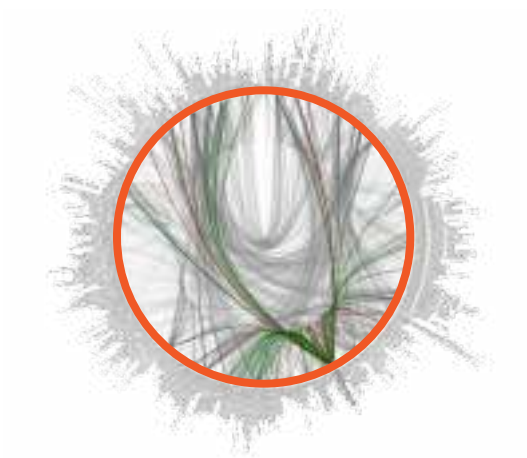
Application Modernization Microservices



Gains

- Developer agility
- Ship independently faster
- Choice of stack

Microservices



Challenges

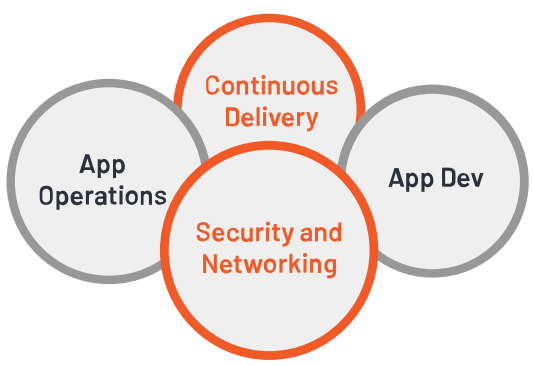
- Resiliency to network failures
- Testing, dependencies, and troubleshooting
- Increased exposure to attack vectors

A twin transformation—so closely associated with cloud adoption that they are usually spoken of in the same breath—is **application modernization**. The main driver for decomposing monoliths to microservices is agility, a theme we'll see crop up a lot: ship more value faster with less overhead, use the right stack for the job, and align with DevOps processes and best practices. And, if you're moving into the cloud, it makes sense to be cloud native, which requires that you modernize your applications.

As always, there are trade-offs--or, at least, new point-in-time challenges to address. Where monolithic applications have the luxury of doing much of their work in a single block of machine memory (or at least in memory and on disk on a single machine), microservices must have a reliable network between them to do pretty memory and on disk on a single machine), microservices must have a reliable network between them to do pretty much anything. Testing, dependency management, and troubleshooting are inherently more difficult in microservices applications because there are many more moving parts. For the same reason, microservices offer a broader attack surface with more potential attack vectors.

Security and Networking (Still) Impede Agility

DevSecOps



Gains

- Declarative security policies in dev process
- Visibility and auditability
- Automation and unified policy enforcement

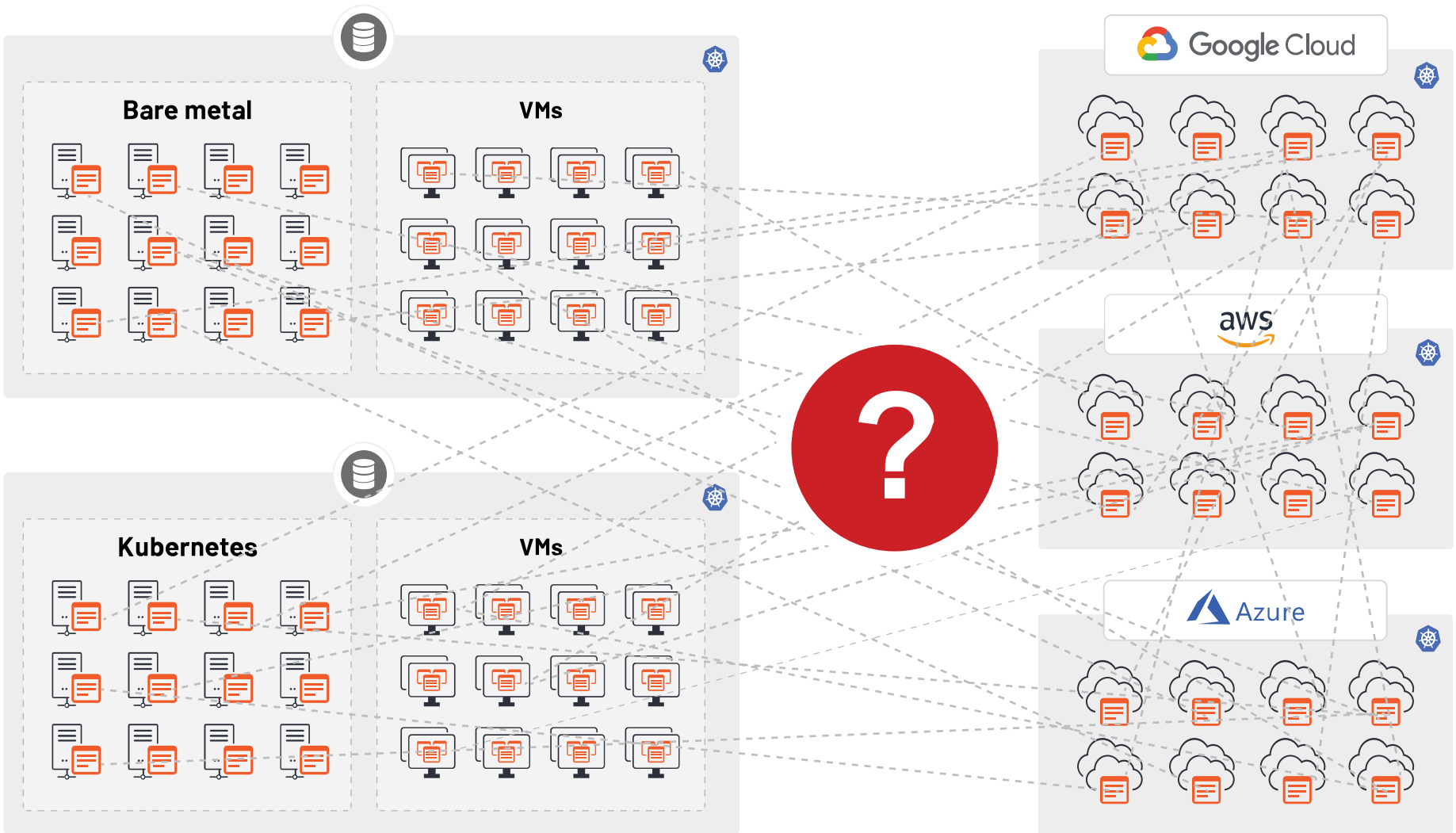
VPNs et al

VPNs et al

- Varied blackbox L3/L4 tooling
- Changes are coarse-grained and difficult
- Lack of end-to-end visibility

Cloud-native applications have the benefit of declarative policy, starting in the development process and extending into production. Increased automation promises more unified policy enforcement. But, **mid-transformation**, many organizations are still trying to connect and secure cloud-native applications with a grab bag of opaque, often manual, L3/L4 tooling like firewalls and VPNs. It remains slow and difficult to make changes to network and security policy; and, at the heart of things, it's difficult to make changes to institutional behavior.

Result: Complexity and Lack of Operational Agility



Precisely because many large organizations are only part of the way through several large, simultaneous technology transformations, many of the promised gains are yet to be realized, while relatively short-term, point-in-time challenges are yet to be overcome.

The current state is in many ways an unfortunate worst-of-all-worlds scenario, with new complexity overwhelming the agility gains of moving to the cloud and microservices.

Unrealized Goals

Agility

- Traffic shaping and canary controls
- Service discovery across multiple clusters and data centers
- On-demand workflows for faster, safer rollouts
- Faster application troubleshooting

Security and Isolation

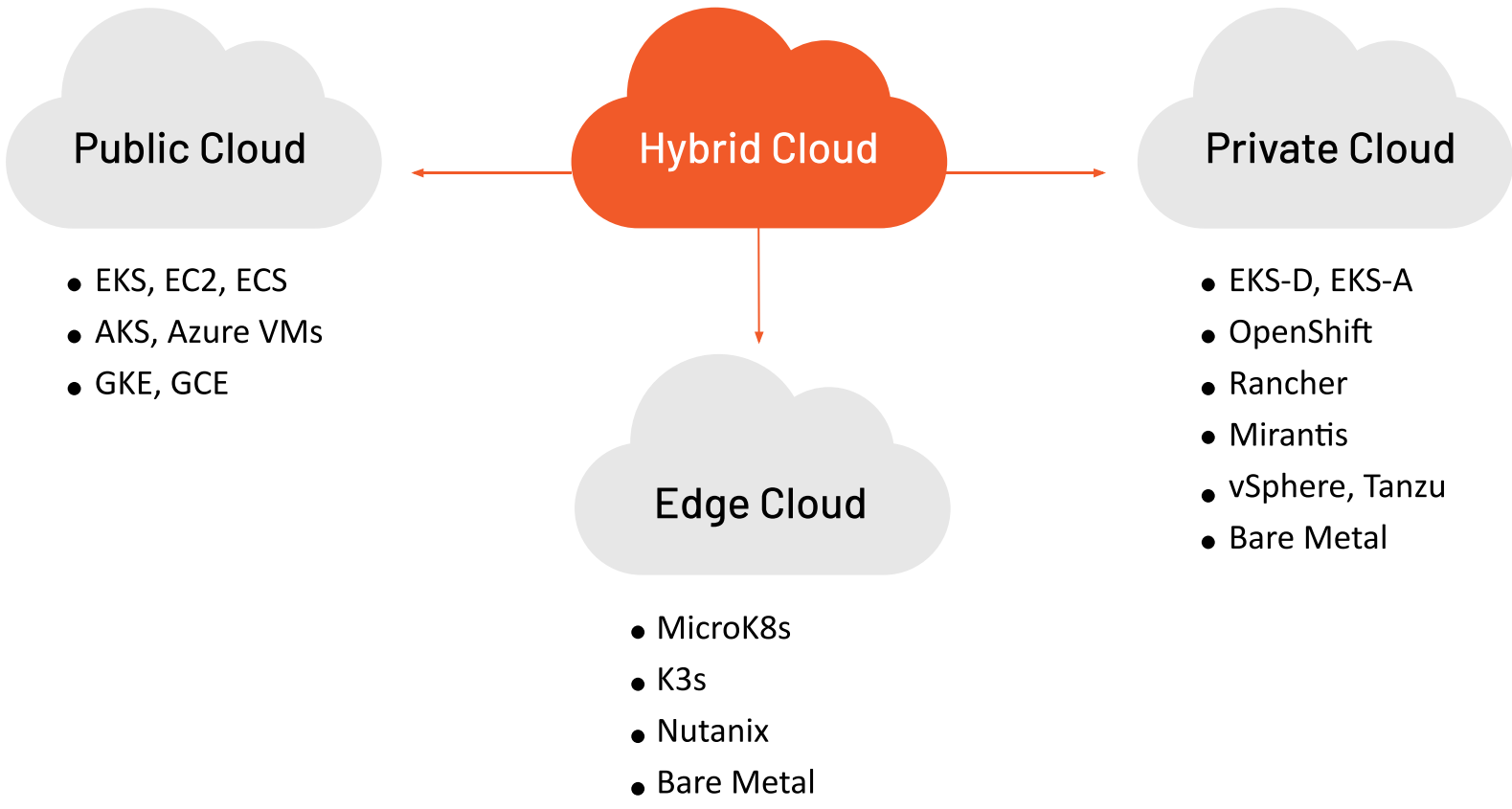
- Multitenancy
- Cross-cluster and cross-cloud security policies and access control
- Application-level segmentation: fine-grained ingress and egress controls
- Secure by default with removal of implicit trust between services

Business Continuity

- High availability and resiliency for active-active deployments
- Unified telemetry and service-level objective management

Mid-transformation, we see many organizations still struggling to achieve goals across three broad categories: agility, security, and business continuity. Agility is hampered by lack of visibility and control over what has become something of a sprawling mess spread among heterogeneous environments across data centers and different clouds, each requiring a different set of tools and practices. Security policy is harder than ever to enforce consistently across these environments, just as it's more important than ever to get right. And, even though the cloud offers near-instant scale, business continuity is at risk from the sheer difficulty of getting quality intel across a sprawling fleet, to allow operators to identify failures, and to route around them quickly enough to avoid outages.

Service Mesh: the Agent of Cross-Cutting Change



Tetrate Service Bridge provides centralized governance with collaborative controls enabling local empowerment

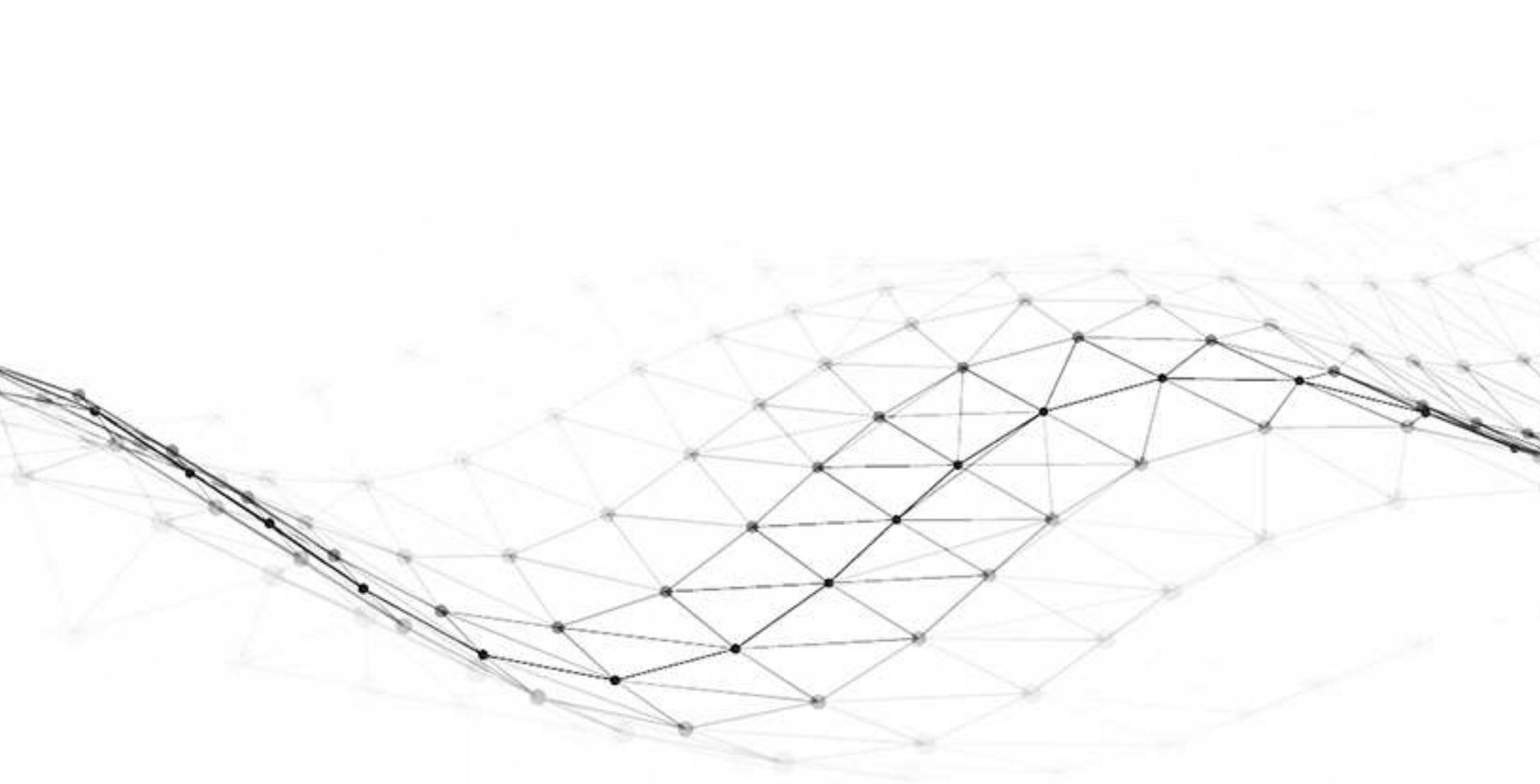
These are the very challenges that service mesh—and Tetrate as a company—were created to meet. Service mesh as a solution extracts the cross-cutting concerns of security, connectivity, observability, and reliability from application code and libraries and into a dedicated infrastructure layer. This layer can be managed centrally and implemented and enforced consistently across different environments, compute architectures, and language ecosystems.

In the following pages, we'll cover:

1. The basics of what a service mesh is and why you need it
2. An overview of the business needs driving our customers to adopt the mesh
3. The ecosystem the mesh lives in, including what it replaces and what it integrates with

Chapter 2

What is a Service Mesh?



Service Mesh

From the beginning, Google faced a challenge: processing massive, and fast-growing, amounts of data in a distributed fashion to provide needed services and power analytics. To meet this challenge, they transformed their internal application architecture from a centralized API gateway to decentralized microservices on a flat network. The service mesh approach evolved to help address concerns that arose in this transformation. And, now that many companies face similar challenges to Google's, the need for service mesh is universal.

The centralized gateway presented multiple challenges: from locality to cache coherency and increased overhead from extra hops. Two of the top challenges were cost accounting and shared-fate outages. It was impossible for the team running the API gateway to perform cost attribution to individual teams using the gateway—making it challenging to control costs and to do capacity planning—as well as being a common root cause for outages affecting business continuity.

This poor fit between a central API gateway and a decentralized service architecture prompted the development of a proto-service mesh, where communication from users to services, as well as communication from services to other services, was handled by sidecar proxies talking directly to each other instead of through a central API gateway.

A sidecar proxy is a piece of software that is put alongside each of the individual services that make up a microservices application. Applications depend on the sidecar proxies to handle communication tasks between services. The mesh is composed of sidecar proxies, with each instance of the proxy deployed beside a single service instance as a sidecar.

The benefits of implementing service mesh at Google were striking. Teams were now able to easily do cost accounting, and shared-fate outages due to an individual team's misconfigurations were essentially eliminated. As teams, and the organization, grew more confident with the mesh, they started to see other benefits they didn't originally expect: it was an incredible tool for implementing cross-cutting features for the entire platform.

For example, before the service mesh, an effort to add three identity access management (IAM) methods to all Google Cloud Platform APIs took 40 teams, each contributing around two engineers, more than six months to implement. It was an organizationally scarring experience. After the mesh was in place, a similar global API update to add policy checks to every resource took only two engineers a single quarter to implement.

Shortly after the service mesh experience at Google, we started Istio to bring service mesh to the world. Listening to Istio's earliest users, we heard a common set of challenges that the mesh uniquely addresses: not just shared fate outages or cost attribution, but difficulty enabling developers to build features for users more quickly while the organization grapples with the transition imposed by modernization and move-to-cloud.

We started Tetrate to build solutions for enterprises grappling with these challenges.

Features, Capabilities, and Architecture

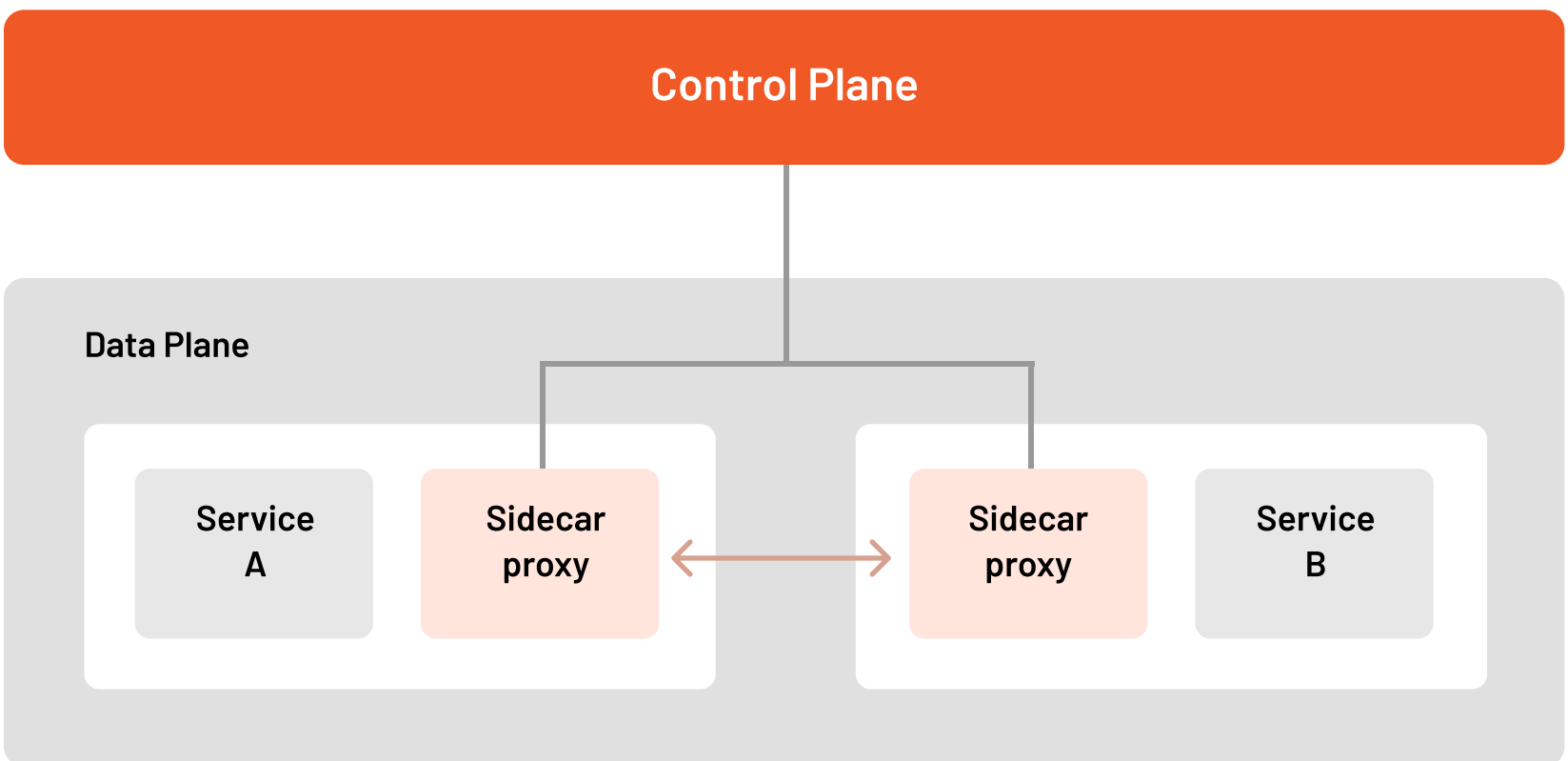


Figure 2.1: *Service mesh architecture*

Service mesh is an infrastructure layer that sits between application components and the network via a proxy. These app components are often microservices, but any workload from serverless containers to traditional n-tier applications in VMs or on bare metal can participate in a mesh. Rather than each component communicating directly with other components over the network, the proxies mediate that communication. These proxies form the data plane, providing a ton of capabilities for implementing security and traffic policy, as well as producing telemetry about the services they're deployed with. They're configured by a control plane dynamically at runtime so policy can be updated on-the-fly (Figure 2.1).

Common capabilities offered to every applicationapplications by the mesh include:

- Service discovery
- Resiliency: retries, outlier detection, circuit breaking, timeouts, etc.
- Client-side load balancing
- Fine-grained traffic control at L7 (not L4!): route by headers, destination or source, etc.
- Security policy on each request, rather than once per connection
- Authentication, rate limiting, arbitrary policy based on L7 metadata
- Strong (L7) workload identity
- Service-to-service authorization
- Metrics, logs, and tracing

All of these capabilities are available to some degree or other in frameworks and libraries today—for example, Hystrix, and Spring Boot and Spring Cloud. (Most innovations in the cloud-native architecture space have focused on the Java virtual machine.) However, by pulling these capabilities out of the application components and into a common infrastructure layer, we get centralized control with distributed enforcement that's just not possible with the rogues' gallery of frameworks and libraries littering the landscape. This common infrastructure layer gives organizations with many applications, written in many languages, and deployed across many different environments the benefits of:

Centralized visibility and control

Consistency across the entire fleet

Ease of change through policy and configuration implemented as code

A **lifecycle** for these capabilities separate from any application lifecycle - which means you don't have to upgrade and redeploy an application to apply, for example, mTLS between components

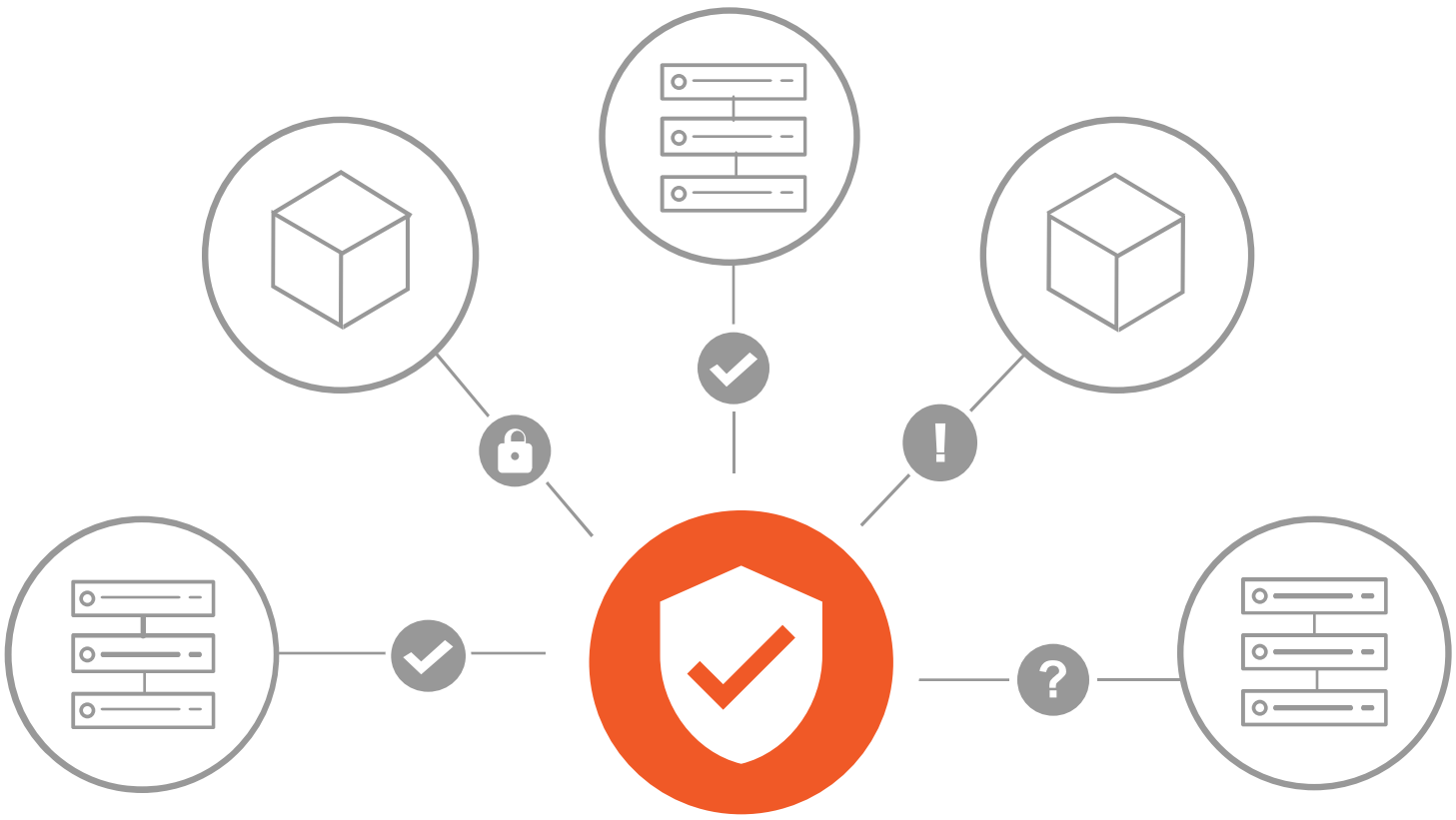
All of this leads to greater developer efficiency, since these considerations are simply removed from the requirements an application must meet. Any concerns or problems in these areas are no longer a concern of the developer.

Istio: the leading mesh implementation

A service mesh is the right architecture for the enforcement of authorization policies since the components involved are moved out of the application and executed in a space where they can form a security kernel that can be vetted

National Institute of Standards and Technology (NIST)

SP 800-204B



The mesh is the **security kernel** for microservices-based applications. As a result, the choice of service mesh implementation techniques has a direct impact on application and information security. The level of intensity around development, bug fixes, and security patches should match the level of trust you expect to place in the mesh as your application security kernel.

Istio is the most widely used (CNCF, 2020) and most robustly supported service mesh, with a history of prompt CVE patches, paid security audits, and currently active bug bounties. And Istio is the only service mesh with an ecosystem that enjoys both grass-roots support and support from multiple institutions, large and small.

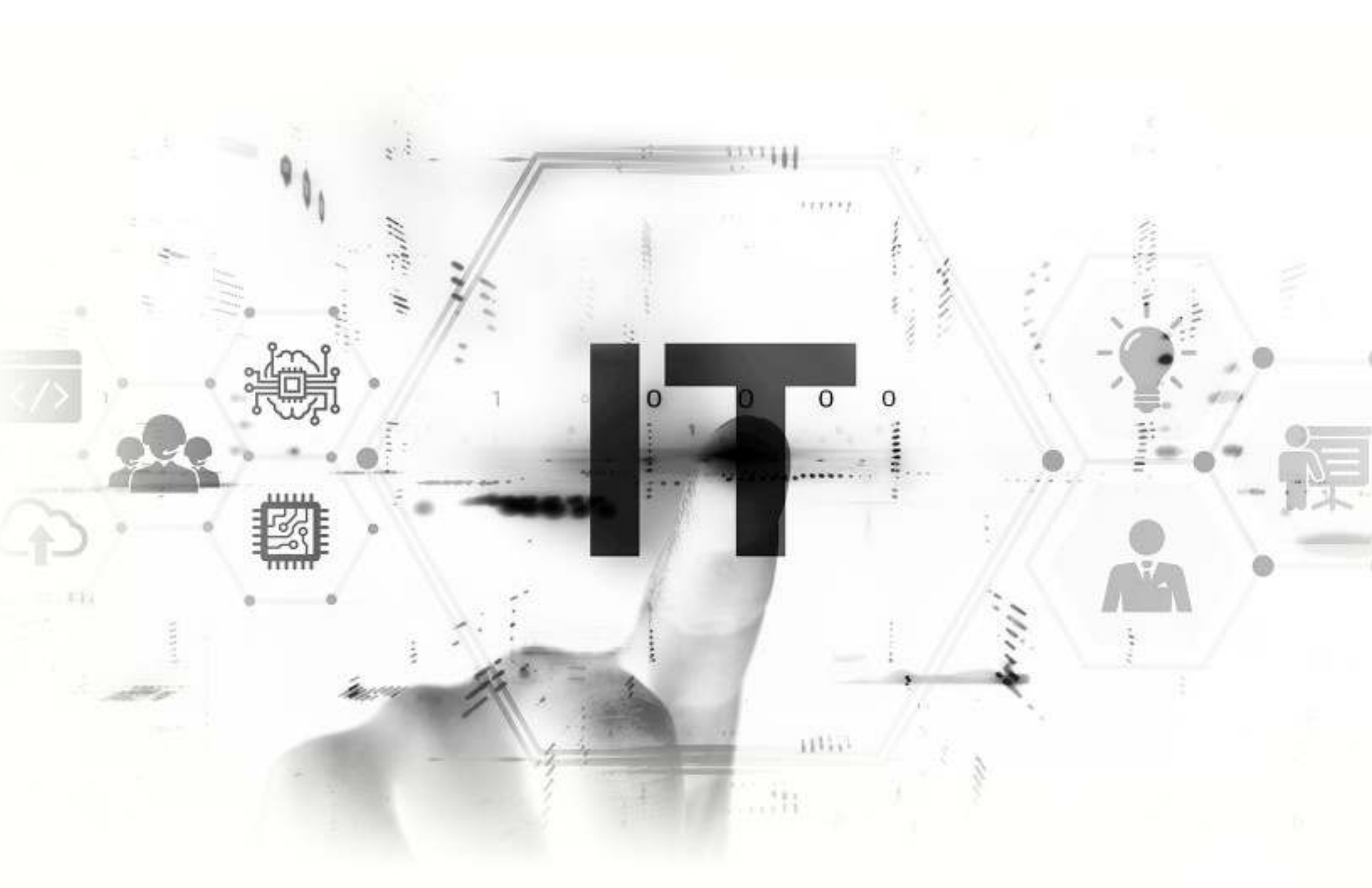
For example, Istio is the reference implementation for microservices security standards developed by the US National Institute of Standards and Technology (NIST), with increasing use in the Department of Defense and the federal government. The NIST microservices security standards are found in NIST, SP 800-204A and NIST,the NIST Special Publication 800-204 series (SP 800-204, SP 800-204A, SP 800-204B, and SP 800-204C). Tetrate has been a major contributor to this series of standards.

Istio is also evolving in tandem with the Kubernetes ecosystem to offer an ever more seamless experience. The new 2.x Kubernetes networking API now uses the Istio networking API. And, as Kubernetes projects like Knative expand the Kubernetes ecosystem, standardization around Istio promises to make service mesh practices seamless across environments and deployment patterns.

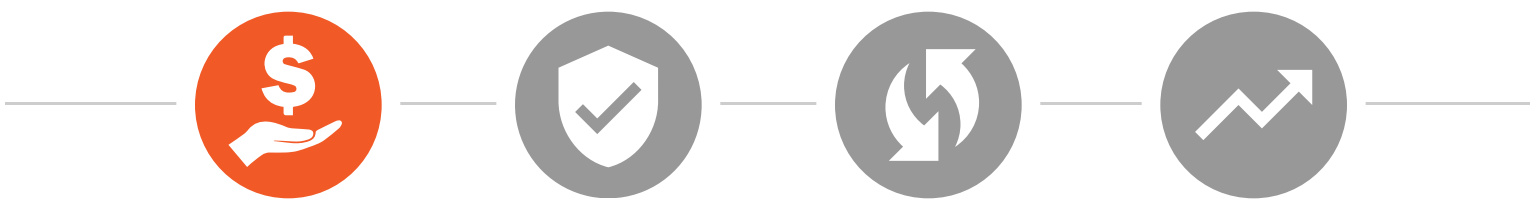
Istio is the name for the service mesh as a whole. The actual sidecar proxy used within Istio is an extended version of a proxy called Envoy. Envoy is written in C++, enabling high performance, and the Envoy proxy is the only Istio component that interacts with data plane traffic.

Chapter 3

Business Drivers: Security, Agility, and Business Continuity



Business Drivers: Security, Agility, and Business Continuity



Although we're in the midst of a large-scale technological transformation, it's the latest in a long history of technological transformations. The curious mind may wonder why we seem to rebuild our software every 10 years. One answer to that question is the cyclical nature of creative destruction: we must take things apart to innovate on particular pieces of technology before knitting them back together into a coherent whole.

Twenty years ago, that creative dismantling was the break-out of business applications from mainframes to rebuild them with n-tier architectures on commodity hardware sliced up into virtual machines (VMs). Over the last decade, we've begun to decompose those monoliths into microservices - which drive, and are also driven by, process innovations like agile and DevOps/DevSecOps. We have also stuffed those bits and pieces into orchestrated containers. Simultaneously, we're breaking infrastructure free from static servers and network devices in data center racks and floating them up to on-demand, automated computing and networking infrastructure in the cloud.

This ontological transformation is not cost-free, unfortunately. Organizations in the thick of this cycle of creative destruction suffer transformation fatigue, as the promised agility and efficiency gains are slow to materialize for many. The expected gains remain elusive largely because the creative destruction cycle is incomplete: we must still re-weave the newly innovated pieces—microservices, DevOps, containers, and cloud—back together into a coherent whole that is better, stronger, faster than before. Across the domains of application security, connectivity, observability, and reliability, the service mesh is the warp and weft of that whole, interconnected cloth.

On this final leg of our transformation journey, the weaving together of applications with a service mesh yields three main business benefits: security, agility, and business continuity.

The increased dynamism and complexity of microservices applications has only increased the challenges for security organizations to meet evolving business, regulatory, and customer requirements for security and privacy. As a result, we're seeing enterprises make a significant shift towards zero trust architecture (ZTA) principles. In fact, a zero trust posture has been mandated for all departments of the federal government.

Unfortunately, some believe that ZTA can be reduced to simply using encryption for all data in transit. While that's part of it, the scope of ZTA is bigger than you may think. To get a sense of what it would mean to fully implement a zero trust architecture, a useful rubrik is: if you took all of your application components and exposed them to the open Internet, what would you need to change? You're at zero trust when the answer to that question is, "nothing bad."

The term zero trust can be confusing. The full description would be “zero implicit trust” or “zero assumption of trust.” In a mesh, each service’s proxy authorizes and authenticates each message, re-confirming trust for each and every message between services. And yes, the messages are encrypted.

Adopting a full zero trust posture for most organizations won't happen overnight. But adopting a service mesh offers a standard, consistent way to close the gap across much of your application fleet.

Out-of-the-Box Security Features for ZTA

Service mesh provides a comprehensive set of out-of-the-box security features available to protect every application component in your fleet, including:

- Strong workload identity
- End-to-end mTLS
- Authentication
- Dynamic, fine-grained authorization
- Envoy as a Policy Enforcement Point (PEP) protecting every workload, whether that's microservices in Kubernetes or VMs in a data center
- Centralized policy authorship with global/distributed policy enforcement

Deep Visibility

The Envoy data plane provides deep visibility into application activities, enabling a feedback loop to improve policy and support real-time detection of attacks, and threat hunting to minimize likelihood of cybersecurity incidents and reduce impact to the business.

Scaling Security Engineering

The global management plane coordinates control planes spanning heterogeneous infrastructure. It also serves as a common administration and collaboration point for security, networking, and application teams. This allows features and configurations to be prescribed, designed, implemented, and delivered within the continuous development process and tooling, offering force-multiplying scale to security engineering. Developers can do most work within guardrails established by security, bringing security and app dev into close collaboration, and bringing the speed and flexibility of agile processes to the security realm.

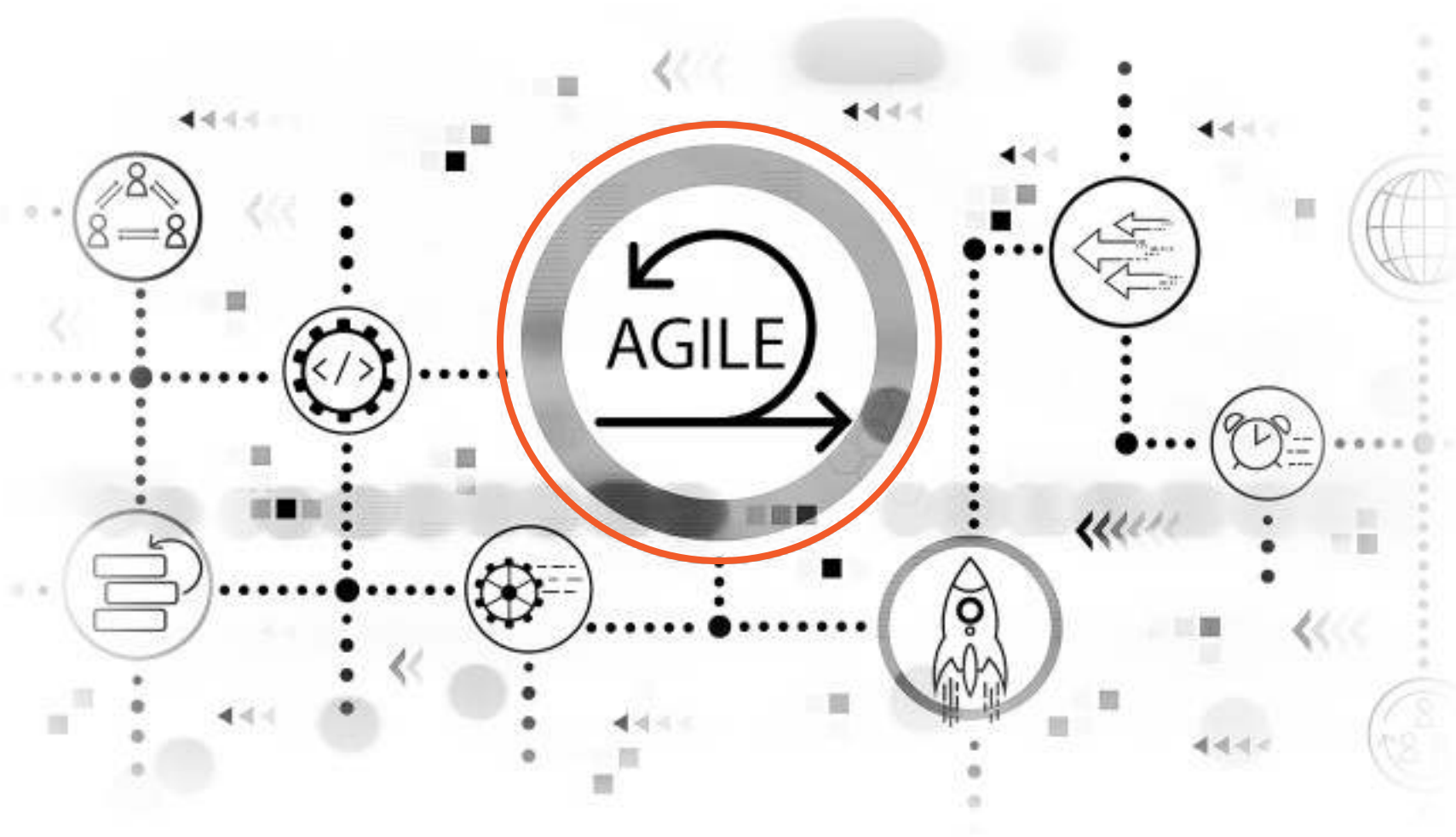
The control and data planes installed in the runtime environment offer consistent security features across heterogeneous app architectures and application stacks. The single admin/ops plane ensures consistent configurations across multiple infrastructure as-a-service (IaaS) providers, such as AWS, Microsoft Azure, and Google Cloud Platform, and on-premises data centers.

Security Standards for Microservices

Tetrate partners with NIST to define and promote security standards. Tetrate founding engineer Zack Butcher is co-author of the NIST Special Publication 800-204 series (SP 800-204, SP 800-204A, SP 800-204B, and SP 800-204C) that sets the U.S. Government security standards for microservices applications. Those standards call out service mesh as the preferred technology for microservices security and Istio as the reference implementation.

Agility

In the world of dynamic, distributed, and heterogeneous services, the mesh offers centralized governance with local enforcement. By concentrating the cross-cutting application concerns of security, connectivity, observability, and reliability into a dedicated infrastructure layer shared by every application, the mesh makes everything more similar, yielding increased operational efficiency. The ad-hoc, semi-manual, semi-scripted bundles of baling wire and chewing gum surrounding and unique to each application's deployment and maintenance can be unwound and replaced with a standard set of automated processes common to every app.



Out-of-the-Box Features for Agility

The service mesh helps us realize agility in our organization by:

- Centralizing cross-cutting concerns (like encryption in transit) into the platform layer, so application developers don't need to worry about them
- Giving us confidence in application rollout and deployment through fine-grained traffic control enabling application canaries, progressive rollouts and A/B testing
- Failover and failback allow you to move quickly but safely

Business Continuity

As with agility and security, we see business continuity threatened by the increasing complexity and opacity of modern deployments, especially as organizations struggle to manage traditional workloads in tandem with their transformation efforts. Heterogeneity makes it hard to implement changes. Complexity-driven opacity makes it hard to even understand what's going on.

Service mesh can help solve this problem, driving business continuity in at least two critical ways. First, by offering seamless traffic shifting across failure domains. The mesh can be smart about locality when all systems are healthy and, failover - shifting traffic away from unhealthy to healthy resources in other clusters, regions, or even clouds, all before downstream requests—and customers—are affected.

Service mesh helps operators implement "safety first" approaches such as canary rollouts (only sending new code to a small percentage of production traffic), A/B testing (assessing the impact of new code for some users against performance of the previous code base with other users), and failback as a way to return to a "known good" status.

Also, by providing consistent and global observability capabilities across applications, the mesh enables a coherent picture of what healthy applications look like, allowing app and ops teams to identify and rectify pathological behavior before it escalates. When failures do occur, the visibility and observability capabilities of the mesh allow for faster troubleshooting and lower mean time to resolution (MTTR) per incident.

Out-of-the-Box Features for Business Continuity

Service mesh provides a great set of features out-of-the-box to help ensure business continuity for applications deployed in the mesh, including:

- Application-level operational metrics (rate of traffic, rate of errors, latency) per request
- Distributed tracing and consistent access logging
- Resiliency capabilities like timesouts, retries, outlier detection, and circuit breaking
- Service discovery and load balancing (including across clusters and clouds)

Chapter 4

Ecosystem

Ecosystem

As a dedicated infrastructure layer to handle cross-cutting security, connectivity, observability, and reliability concerns, the mesh sits on top of lower-level compute and networking infrastructure, mediating application-level communication between individual components as well as the outside world. As such, service mesh is part of a broader ecosystem and provides key integration points to critical systems outside its primary domain of responsibility.

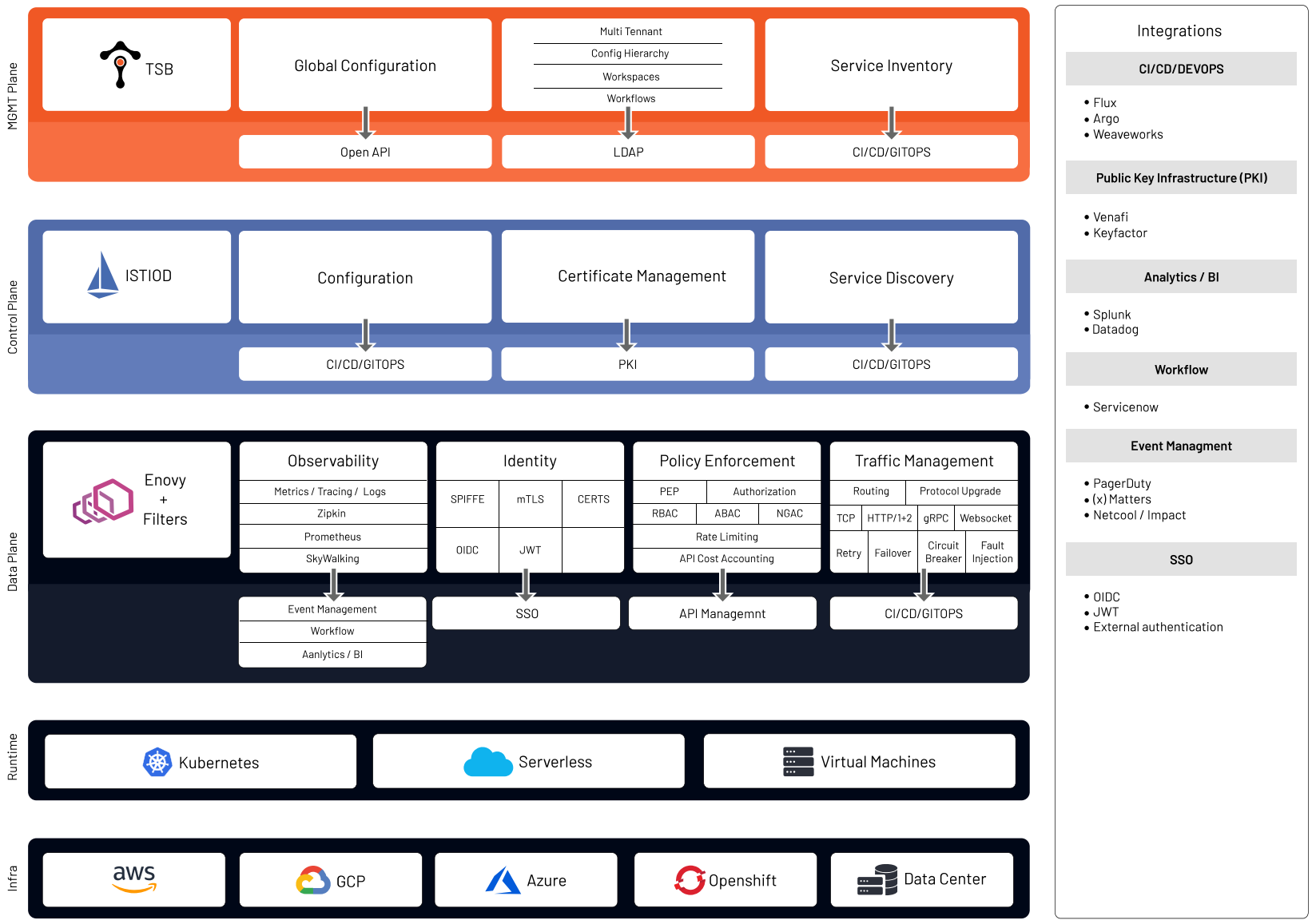


Figure 4.1: *Service mesh ecosystem and integrations*

Service Mesh Integrations

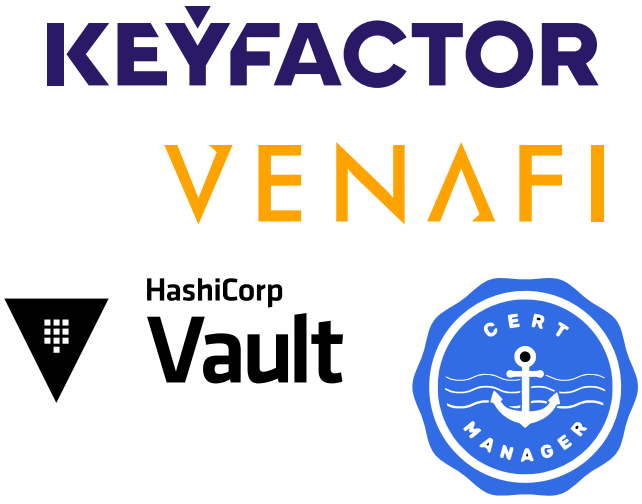
CI/CD/DevSecNetOps/GitOps

Because Istio is driven by policy-as-code, it fits naturally into existing git-driven workflows such as other Kubernetes objects.

Notable third-party code pipeline integrations

Public key infrastructure (PKI)

Istio manages certificates as part of its built-in mTLS capabilities. Its internal certificate authority (CA) can be configured with a root certificate & signing certificate and key, DNS certificates, and custom CA integration using Kubernetes certificate signing requests. Tetrate Service Bridge (TSB) offers extended integration with third-party public key infrastructure providers.



Notable third-party PKI integrations

Analytics/business intelligence (BI)

As Google found at the beginning, getting consistent and actionable runtime data out of your applications is a core value proposition of service mesh. Sharing that data with your analytics and business intelligence infrastructure is part of the fun.

Notable analytics/BI integrations

Notable business process/workflow integrations

Business process/workflow

TSB also allows you to plug into third-party workflow automation systems to, well, mesh with the way you already do business.

Event management

TSB integrates with your event management system. Think of it as an extension of observability capabilities of the mesh to fit into the way you handle event alerts and notifications: modern visibility and observability injected directly into your organization's brain.

Notable event management integrations

Service identity, authentication, and end-user credentials/SSO

Identity, authentication, and authorization are central concerns of the mesh. Out of the box, you get runtime service-to-service identity. For runtime integration with your existing identity provider, TSB offers OIDC and JWT support.

TSB's management plane also syncs with your enterprise directory service to let you define and manage access policy, using the same users and roles that the rest of your organization does.

Chapter 5

Tetrate Service Bridge

Tetrate Service Bridge

Tetrate's flagship product, Tetrate Service Bridge, goes beyond stock Istio, offering enterprise-grade features designed to fit an organization's existing people and processes, making the modernization journey easier by meeting you where you are. Under the hood, TSB uses Istio and Envoy to provide local control and data planes, with an overarching management plane to orchestrate configurations and collect telemetry data across heterogenous compute environments.

Edge-to-Workload Topology

TSB's topology spans 1) the application edge, with a Tier 1 gateway configuration; 2) application ingress, with ingress gateways in each cluster; and 3) a sidecar next to each service.

Application edge. Envoy-based, application-aware L7 gateway smart and flexible enough to facilitate modern multi-cluster deployments.

- Request-level traffic control across all compute clusters
- Traditional north-south API gateway functionality
- Single sign-on (SSO) for applications deployed in the mesh, without changes to the applications thenselves
- Web Application Firewall (WAF) functionality for east-west in addition to north-south

Application ingress. Envoy-based, application-aware ingress load balancer combines service mesh ingress with backend API gateway functionality.

- Kubernetes ingress & service load balancing
- Traffic shifting between VMs and Kubernetes across cloud and on-premises
- Traditional east/west API gateway functionality, such as rate limiting and credential management
- Fault tolerance capabilities like timeouts, retries, and circuit breakers

Application egress. Envoy-based, application-aware egress load balancer gives you the capabilities to control how your applications communicate with services outside of the mesh.

- Hostname and SNI-based allow/deny listing
- Control which services can communicate out with fine-grained access control
- Traffic control for communicating with services outside of the mesh, including load balancing, timeouts, retries, and circuit breakers
- Credential exchange - store and maintain API keys or client certificates on the egress proxy rather than the application
- Detailed metrics to understand how you're consuming services outside of the mesh

Service mesh. In-cluster, Envoy sidecars connect individual workloads, serving as per-workload gateways. The Istio control plane applies configuration to sidecar proxies, as directed by Tetrate's global management plane, and sends telemetry data back to it.

Global management plane. A central management plane coordinates policy, configuration, observability, and lifecycle across an entire application network topology to offer:

- Centralized management
- Multi-tenancy
- Global service inventory
- Configuration safeguards

Tetrate's Enterprise Service Mesh Features and Capabilities

Next-Generation API Governance

Because the mesh puts gateways around each workload and the management plane maintains a global view of application traffic, there is no practical difference between north-south and east-west traffic in a Tetrate-managed mesh. There is just application traffic. Out-of-the-box API management functionality may be applied at every layer: application edge, application ingress, and between services at the sidecar proxy. Those API-focused features include:

- **OpenAPI:** Configure gateways and the mesh with your OpenAPI spec
- **CORS:** Policy configuration
- **Authn/z:** mTLS, OIDC, JWT, IP blacklist/whitelist, integration with external auth services
- **Credential management**
- **Rate limiting:** Edge-to-workload and service-to-service
- **Fault tolerance:** Timeout, retry, circuit breaker
- **Transforms:** Custom header and body transforms for both request and response
- **Wasm:** Deploy custom Wasm filters to Envoy

Web Application Firewall (WAF)

TSB offers the inclusion of ModSecurity—implemented as an Envoy filter and configured by the global management plane—at every gateway and sidecar with support for reusable rule sets and the OWASP core rule set.

Global Application and Organizational Awareness

Centralized management. While Istio is the de facto standard service mesh for single-cluster Kubernetes, TSB adds a global management plane that extends Istio to multi-cluster, multi-cloud, and hybrid cloud deployments on any compute.

Secure multi-tenancy, workspaces, and hierarchical permissions. TSB makes it easy to control who in your organization can change what, audit those changes, and ensure your application deployment conforms to best practices for security. Tenant, workspace, and application constructs provide permissions guardrails between application teams operating in a shared cluster environment, so each team can have ownership over its own application resources without stepping on each other's toes. It's also possible to give infrastructure admins privileges specific to their area of expertise.

For example, security admin permissions may be configured to allow updates to TLS certificates, but deny adjustments to traffic routing rules. Hierarchical permissions enable admins to configure top-level default policy that is automatically inherited down to tenants, workspace, and application levels, ensuring consistent policy enforcement for every application. This allows security, network, and application administrators to cooperate in a shared configuration environment

Global service inventory. TSB's management plane offers a comprehensive view of every application, wherever it runs--in modern or traditional deployments--including real-time health checks, endpoints, and performance. Whether in data centers or the cloud, VMs and containers are observable and managed with a consistent set of tools and processes.

Configuration safeguards. TSB's configuration validation ensures correctness by construction. Service-level isolation and organizational controls guarantee that only correct configuration reaches production workloads.

Comprehensive Istio & Envoy lifecycle management. Tetrate takes the complexity out of upgrading Istio and Envoy everywhere. The lifecycle is managed centrally and deployments may be upgraded incrementally with a full inventory of mesh deployments, versions, plus current and auditable historic state.

Security

Tetrate simplifies policy enforcement by extending the capabilities of a single-cluster service mesh to an entire application fleet. App-level zoning allows for secure, fine-grained segmentation. Vetted workflows allow application, platform, and infosec teams to effectively manage policies for the entire organization. A centralized view of config changes with policy controls enables audit and continuous proof of compliance.

Compliance. Tetrate Service Bridge works with the FIPS and federally certified Istio builds created and supported by Tetrate. It offers PCI DSS conformance, plus out-of-the box controls to ensure compliance with regulatory requirements. Audit log exports are also available to provide proof of current and historical adherence to governance and compliance standards.

End-to-end mTLS. Tetrate Service Bridge integrates with existing public key infrastructure--including ACM and Venafi--for centralized management. And TSB supports Istio's ability to enable encryption to be implemented consistently and flexibly across all workloads, including between containers and VMs. Mutual TLS enforcement can be applied by security teams according to governance policy, without relying on the capacity and timelines of app teams to build support for it into each application.

Secure access. Tetrate's built-in implementation of NIST's next-generation access control (NGAC) provides for fine-grained, flexible segmentation, authentication, and authorization. Move auth out of your applications to unburden your developers. Perform access control in Envoy between services to ensure consistent policy enforcement across your entire fleet and manage it all in one place.

Policy-driven. The mesh takes cross-cutting security concerns out of the application code stack and into a dedicated infrastructure layer where they belong. Security teams have centralized control of policy for every application, regardless of which language or technology stack they use. This gives security teams the visibility and control they need to keep applications and data safe, while freeing up app dev cycles to return focus to creating business value.

Connectivity

While single-cluster service mesh facilitates connections between workloads, TSB enables seamless connectivity across heterogeneous, multi-site deployments. TSB offers simple, consistent workflows for managing connectivity, regardless of where applications are deployed and what compute they run on.

Multi-cluster, multi-platform, multi-cloud. From the start, Tetrate's mission has been to connect hybrid networks and compute environments—including multiple clusters, multiple clouds, and on-premises—and to operationalize application networking in a simple, consistent way across an entire fleet. Now, Tetrate brings infrastructure-agnostic communication and operation of the stack.

Seamless communications and management. Runtime service discovery for all apps allows for seamless application communication spanning an entire enterprise infrastructure, from multi-cluster to multi-cloud, monoliths to microservices. The global service inventory allows for mapping application components to the right teams with the right tools to ensure apps can be managed efficiently and safely.

Standardized. Ship code faster by standardizing the way your applications communicate. Replace patchworks of custom gateways. Instead, offload security, connectivity, and observability to the mesh to increase agility and operational efficiency across your organization.

Observability

Tetrate's observability capabilities offer a comprehensive view of application metrics infrastructure, allowing operators and app teams to understand dependencies and application health at a glance. This whole-app context makes it easier to troubleshoot and can reduce mean time to recovery. Tetrate's observability tooling facilitates applying service level objectives globally and consistently to all applications, without having to build instrumentation into the application stack.

Consistent SLOs. Being able to see the topology of services and their dependency relationships makes it easier to measure and understand application health at a glance. Correlated metrics, traces, logs, and lifecycle events make it easier to troubleshoot apps and reduce MTTI and MTTR.

Consistent signals. Service mesh provides a way to get a consistent set of both service and app-level signals from all services in a cluster. Tetrate offers that same consistency across all applications and ensures alerts get to the right teams, so they can take action quickly when issues arise and before downstream customers are affected.

Behaviors. TSB allows operators to collect consistent baseline metrics for all apps without having to get them from each app team. They can create, measure, and monitor both app and service-level SLOs for every application and use that in-depth knowledge of app behaviors to recognize anomalies and take action before users notice.

Reliability

TSB provides built-in high-availability capabilities layered over Istio's reliability primitives. Its distributed, autoscaling ingress layer plus tools to manage transparent failover—from a manual "big red button" to touch-free, automatic failover—allow for traffic shifting to healthy resources. The context of running services provided by TSB, including their dependencies and where they're deployed, helps teams to understand the global health of their applications, measure how their apps behave, and equip them with the tools needed to build resilient systems.

Release cadence. Built-in tools let you measure when it's safe to release newly deployed versions of your services to live traffic. Tetrate Service Bridge allows developers to move quickly, but safely roll back to a known-good state when needed.

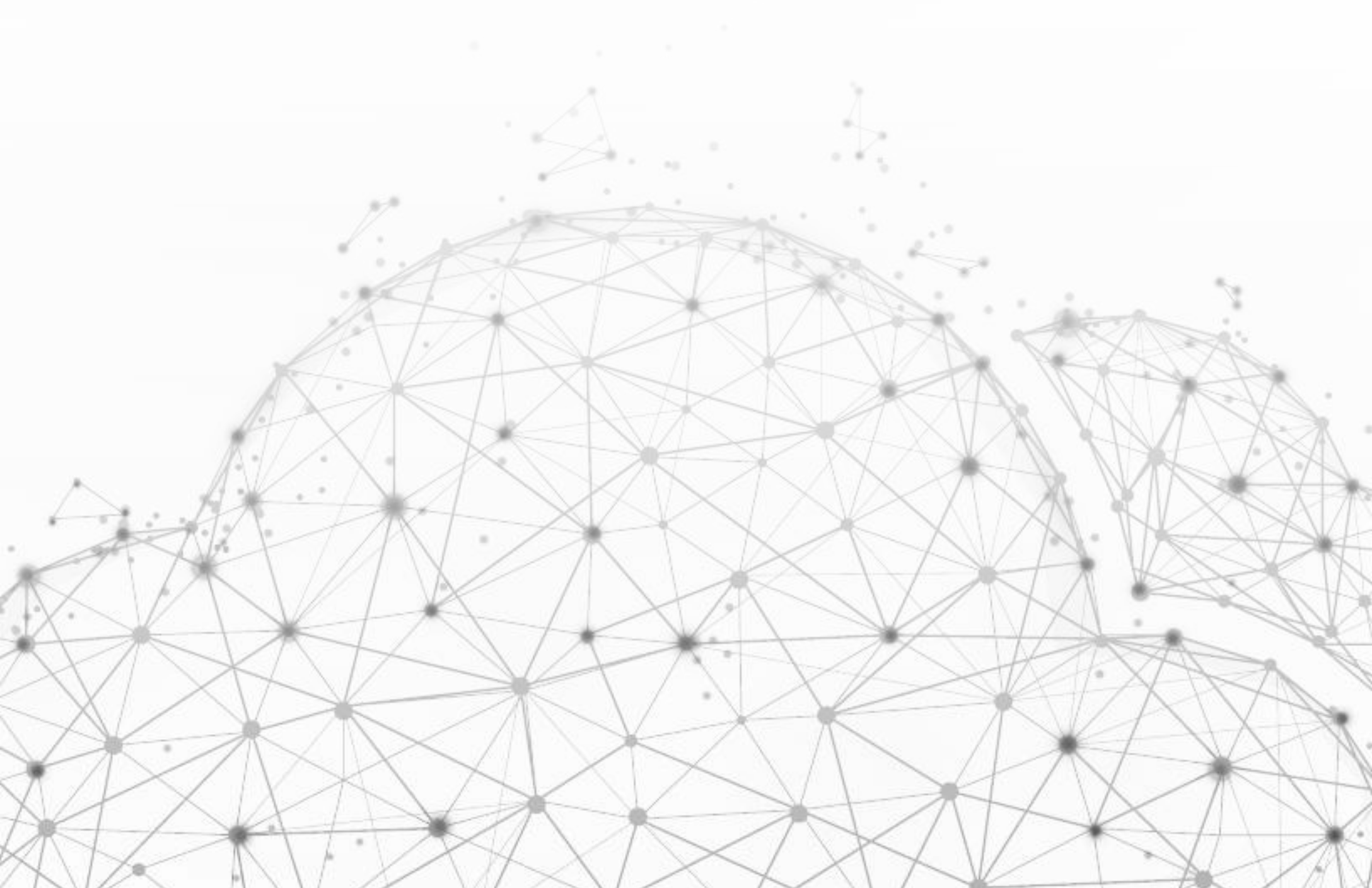
Traffic migration. App teams have the tools they need to understand their applications' health and take action on early indicators with the best information possible at their fingertips.

Lifecycle. TSB reduces the onerous labor and mitigates the risks of updating new app versions as well as the underlying mesh infrastructure. App teams get primitives for fast, safe application updates. Platform operators get tooling to keep application infrastructure up-to-date.

Load balancing. Offload reliability concerns to the mesh by using built-in recovery features like timeouts, retries, and circuit breakers. Increase the ability to mitigate cascading failures with client-side load balancing. Decrease latency and minimize egress costs with locality-aware load balancing that ensures local traffic stays local.

Chapter 6

Service Mesh Adoption Path



Adoption Path

However you choose to tackle service mesh adoption, there is a fundamental set of concerns that need to be addressed to be successful:

Cultural Change

Introducing a new infrastructure component, especially something as fundamental as a service mesh, always requires cultural change. One of the core powers of the service mesh is that it centralizes control and enables small, specialized teams to impact the entire organization. It may require a shift in an organization's engineering culture to fully realize the benefits of this capability.

Education

As we introduce new infrastructure with new capabilities, we need to educate different stakeholders within the organization on those capabilities and how they can leverage them. In the case of the service mesh, which has far-reaching capabilities, this means working with the platform, security, networking, application developers, and operations teams – nearly the entire IT organization.

Operationalization

Any new infrastructure component requires some degree of time, effort, and experience to mature from a proof of concept to a fully operational part of critical production infrastructure. In addition to training and education, new infrastructure requires additional processes and tooling to be developed, including playbooks, dashboards, and alerting. Provisions must be made for edge cases that don't arise in test environments. Over time, we build expertise and increasing confidence in operating the system.

Another key element of operationalizing the service mesh is to abstract away its moving parts from application developers. This gives more consistency and homogeneity, which makes adoption simpler.

Tooling

A key component of operationalization is developing (or augmenting existing) tooling, processes, and pipelines. The platform and operations teams will need tools to understand and troubleshoot production issues. Application developers will need tools to understand how their application interacts with the mesh, sometimes in unexpected ways. There will likely be changes to CI/CD pipelines and so on.

Operationalizing also means leveraging net-new capabilities the service mesh provides. For example, consistent metrics for all applications enables you to offer a single, consistent, reusable set of dashboards to production and application teams, reducing the time it takes to bring new services into production and improving their overall production operability once they get there. The same is true for logging, tracing, security controls, and capabilities like safe deployments via canaries.

Process Change

As with any infrastructure investment, these education, operationalization, and tooling updates, and the cultural adaptations that accompany them, will require some process changes to fully realize the value of a service mesh.

We see organizations adopt the mesh most successfully when they minimize changes to existing processes for applications development teams. As your investment begins to demonstrate value to the organization in concrete ways—e.g., enabling encryption in transit for all applications without needing to involve application developers—you develop the political will within your organization to introduce larger process changes, which will, in turn, unlock more value from your existing infrastructure investment, in a virtuous cycle.

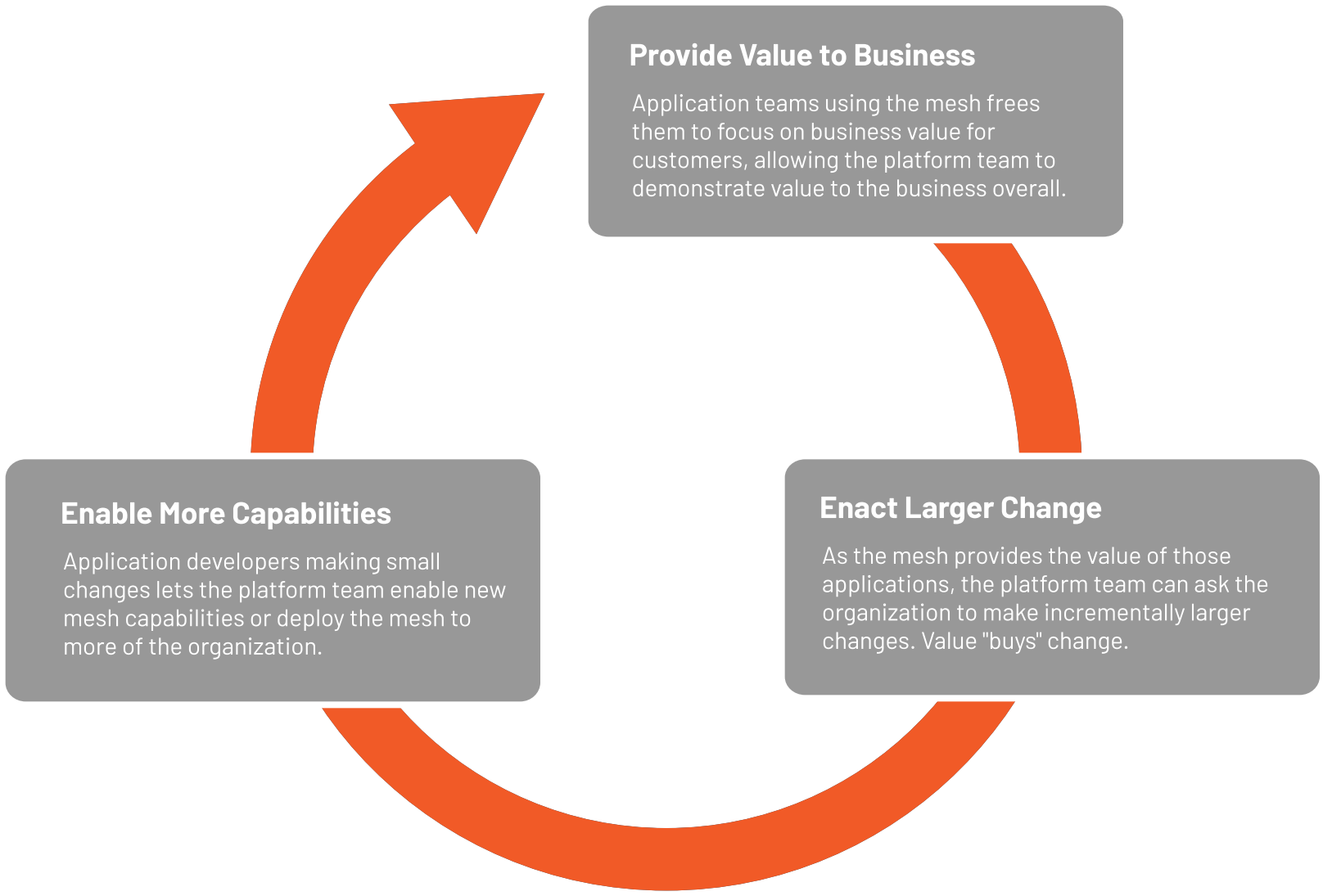


Figure 5.1: *The virtuous cycle of providing value to the business, which provides the political capital to ask for slightly larger changes for the sake of the platform, which allows the platform team to enable new or more capabilities, which then provides more value to the business.*

Time to Value

Perhaps the most important concern for any infrastructure improvement is the time it takes to demonstrate value. Showing a steady stream of incremental value early on builds the political currency to "pay for" larger process and cultural changes to the organization which, in turn, allow you to show greater value. Those increments may often have a large impact.

Platform-Driven Adoption

To understand the typical mesh adoption pattern, it's instructive to cover the general adoption flow we see used by most of our customers. The service mesh adoption effort tends to be driven by a platform team whose purview includes how application developers get their apps to work in the organization. The platform team works closely with other central teams in the organization to prepare for service mesh adoption.

Team	Typical Collaborations
Security	• The security model for the platform, including the mesh • Integrations with existing public key infrastructure (PKI) • Overarching policies like how the mesh works across segmented networking architectures with a DMZ, application, and data zones
Networking	Establish the pattern for integrating the mesh with existing networking infrastructure, including: • Load-balancing appliances • Shared API gateways • WAFs • GSLB
Infrastructure	Capacity planning
Operations	• Training programs • Runbook development
Application	Preparation of early-adopter application teams

After aligning these stakeholders, the key decision point becomes: how do you onboard applications into the mesh? Getting applications onto the mesh, and getting application developers to leverage the capabilities they get as a result, is the long tail of any mesh adoption. However, as the service mesh platform gains more adoption within the organization, it will radically streamline the cross-team collaboration required to deploy and manage applications.

Where application teams were previously required to interface with all of the central teams individually, the service mesh platform and the team that runs it become a central hub to facilitate the concerns of security, networking, operations, and infrastructure teams, while application teams need only interact with the platform. This greatly simplifies application teams' responsibilities, reducing operational overhead while increasing agility.

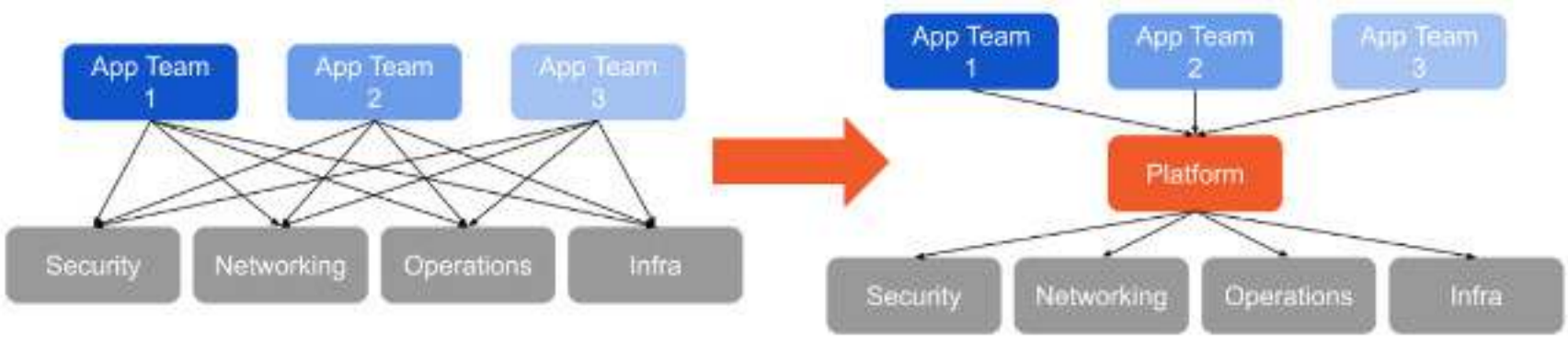


Figure 5.2: *The platform streamlines cross-team collaboration*

A Phased Approach: Adopting the Mesh, Application by Application

Based on years of experience helping organizations build a service mesh practice, we recommend a phased approach whereby we bucket applications into groups sharing certain common attributes, then onboard one application group at a time. This allows us to realize many benefits of the mesh and establish general practices for that entire group of applications.

We also build production and operational experience that we can apply to enhance the onboarding experience of the next group. Each new group of applications we onboard tends to be incrementally more critical, or presents additional complexity compared to the group before.

We commonly bucket applications into groups along the following vectors:

- Application criticality
- Runtime requirements, including:
  - PCI vs non-PCI
  - Network zone: DMZ vs application vs data tier
  - Deployment environment: containers vs Kubernetes vs VMs vs bare metal
  - Compute architecture: ARM vs x86
  - Low-latency/high-performance vs. less demanding
- Language and framework, e.g. J2EE, Spring Boot, .NET, Node, golang, etc.
- Protocol:
  - Layer 7/request-oriented protocols like HTTP, gRPC, websockets, Thrift, etc.
  - Layer 4/stream-oriented protocols like MySQL, Redis, general TCP, etc.
- Other concerns: organizational (e.g. grouping by business unit), disaster recovery strategy (failover-based, active-active deployment, etc).

This exercise tends to yield between 10-20 groups of applications. We then start with less critical, "well-behaved" applications like newly minted microservices in Kubernetes, then move on to services in common frameworks that speak HTTP/REST, and eventually VM and bare-metal applications. We work our way up incrementally until we reach the most critical applications with the most stringent runtime requirements.

Anecdotally, we see the 80-20 rule at play frequently here, where roughly 80% of applications can be onboarded with relative ease, while the remaining 20% require additional tooling and effort and, in some cases, changes to the application itself.

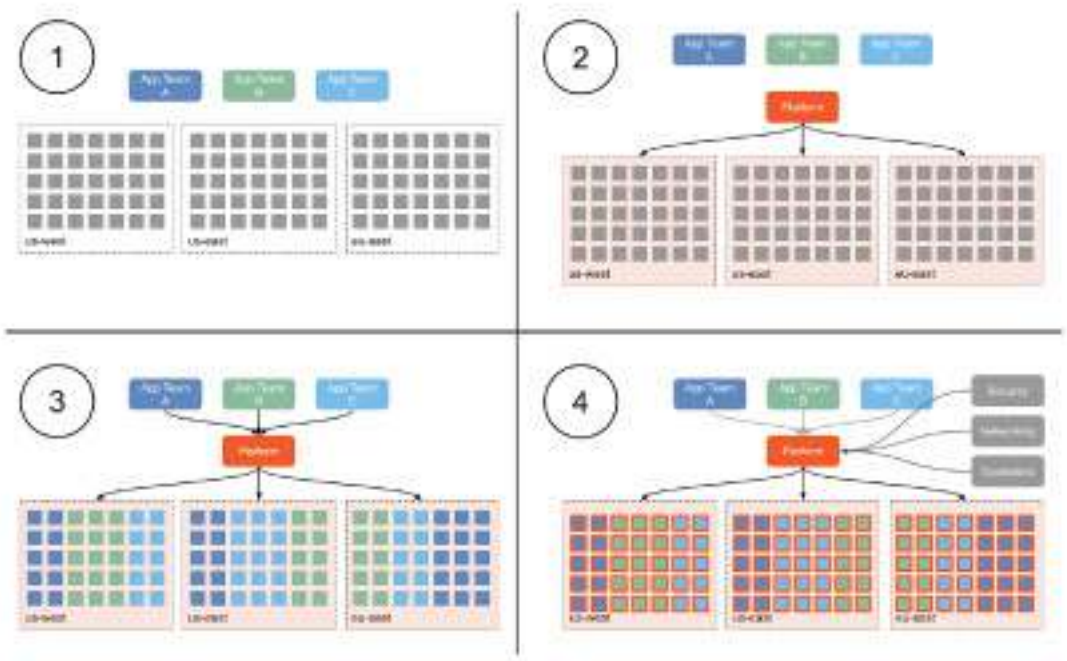


Figure 5.3: *An effective platform helps hide infrastructure concerns from application teams, provides tenancy and ownership for applications running on that infrastructure, and acts as a single integration point for central teams to enforce policy across all applications, without needing to involve application teams (most of the time).*

Benefits of Incremental Adoption

- **Cultural change.** The biggest virtue of a phased approach is the limited organizational and cultural change needed in the early stages, before the mesh has clearly demonstrated its value. Only a select few application teams at a time need to be educated and enculturated, making the process more manageable for organizations with many teams.

- **Education.** As with cultural change, the educational lift is bounded: only a select few teams at a time need to be educated, and typically the platform team can control which teams those are.

- **Operationalization.** The biggest benefit of the phased approach is gaining experience, skills, and confidence with the new system in a low-risk environment first, then gradually increasing the risk by onboarding new, more critical application groups only as confidence in operations and operational expertise increases. Additionally, you can realize many benefits of the mesh for a group of applications—eg., mTLS, and metrics, and logs, and traffic controls—rather than only one application at a time.

- **Tooling.** Onboarding similar applications together creates an opportunity to develop tooling, processes, and templates that work effectively with that group of applications. Building this "happy path" reduces friction for application teams and accelerates their ability to realize value from the mesh.

- **Process change.** Working with smaller groups of teams and specific types of applications gives us more leeway to ask them for process change. We'll need that leeway, because the first few groups of applications are where the platform team becomes familiar with the mesh and develops its operational muscle. This will be especially apparent in the first few groups, and as we build out the tooling and processes for that group that will become common across the organization. As the platform team builds a practice of onboarding new applications, doing so becomes easier, with fewer process changes required.

- **Time to value.** Perhaps the most important result of this approach is generating a steady stream of value for the organization throughout the entire mesh adoption process. Onboard "easy" applications quickly and realize value right away as you develop the tooling and processes needed to bring more challenging groups of applications into the mesh.

Challenges of Incremental Adoption

- The total amount of time to adopt a mesh across the entire organization can be longer than a "big bang" approach. However, you'll show initial value more quickly, and benefit from a continuous stream of value at more regular intervals.

- Covering the last 20% of applications may be a long process taking roughly as much work as the entire first 80%.

Special Case: A "Big Bang" for Homogenous Application Environments

While not the most common case, a significant number of organizations we work with have relatively homogenous application stacks. For example, most of their business applications might use Spring Boot and run in Cloud Foundry. In the same vein, some organizations have invested in strong platform abstractions already. In these cases, we can take a slightly different approach to service mesh adoption, which we call the “big bang”. We do more prep work up front, but that work enables us to onboard a large swathe of the organization onto the mesh in a single push.

As a result, it takes less time overall to complete rolling out the service mesh to the entire organization, at the expense of greater effort up front and a longer time to realize initial value. In this case, we typically focus on deploying one or two key capabilities or features of the mesh for all applications at once, rather than deploying many features of the mesh for a single group of applications before we move on to the next group, as in the phased approach. For homogeneous application environments, this is equivalent to executing the phased approach where the organization only has two to three buckets of applications.

Challenges of the Big Bang Approach

- Some parts of the mesh adoption cannot be done centrally: for example, implementing and maintaining access control policies for every service. At some point, even with a wide approach, you have to bring application teams into the fold with training and guidance, as well as the ability to (safely) change that configuration.

- There is more initial stress on the platform and operations teams, as they have much more exposure to the entire organization but have had less time to adopt new operational practices.

How to Choose an Adoption Pattern

For organizations with a wide variety of applications, many application teams, and highly critical applications, we recommend the phased approach as the safest and surest path to successful adoption and operational readiness of the service mesh. It is the default path we recommend to enterprises looking to adopt a service mesh.

For organizations with strong existing platform abstractions, or those that have a homogenous application mix, the “big bang” approach requires less overall work than an incremental approach and should be seriously considered. However, you cannot escape some amount of incremental work for individual application teams to fully realize the value of the service mesh investment.

Execution Outline for Service Mesh Adoption

Here we've included a high-level checklist of the typical execution path for service mesh adoption. While not exhaustive, it should serve as a useful set of guideposts as you’re developing your own service mesh adoption plan.

Preparing Your Teams

Prepare the teams you’ll be working with, usually concurrently. The goals for this stage are to establish how the service mesh will fit into your existing infrastructure and processes. You'll know you're ready to move forward when you’ve established a plan for each of the key areas we list below, and the teams you’re working with are committed—and, ideally, excited—to adopt the mesh and experience its benefits for themselves.

Adoption Path Checklist

Security

Work with the security groups and the CISO office to:

- [ ] Build the mesh security model for your organization. A few important areas to explore:
  - [ ] How does the mesh fit in with the DMZ?
  - [ ] How does the mesh fit with the existing firewall/WAF?
  - [ ] How does the mesh fit with existing SSL termination?
  - [ ] How does the mesh fit with existing API Gateway appliances?
- [ ] Develop a PKI/certificate strategy for the mesh. Determine what integration work is needed:
  - [ ] Will the mesh issue certificates out of the organization's existing root, or from a separate root of trust?
  - [ ] Will the mesh issue certificates or will you use existing certificate infrastructure for workload certificates? Depending on the approach, this may require changes to those certificates for the service mesh's authentication capabilities to work.
  - [ ] How will we choose to deliver signing certificates to the mesh control plane?
- [ ] Determine what policies the mesh will enforce from the outset.
- [ ] Onboard service mesh containers into your system, with all required security scanning.
  - [ ] Put a process in place to keep these images up-to-date at a regular cadence. For reference, Istio releases four times a year.
  - [ ] Put a process in place to address CVE/image scanning and pentest results for the mesh infrastructure.

Networking

Work with the networking team to:

- [ ] Assess how the mesh changes networking models in your organization.
  - [ ] For example, you may eliminate hairpin traffic from apps that communicate "internally" by going out to a global load balancing system and back through the DMZ and into the datacenter, even when the two workloads run on the same rack. This will have an impact on networking and security.
  - [ ] Determine where TSL (SSL) termination needs to happen. In existing load balancers, offload it to the mesh, or even the application.
  - [ ] Determine how you will manage and deploy the mesh's gateways.
  - [ ] Determine your gateway deployment model: one gateway per team; a single shared gateway for all teams; or mostly shared, with a few standalone. We recommend a gateway per team to start with.
  - [ ] Develop a strategy for how to integrate the mesh with other networking components. For example, how does the mesh fit with existing API Gateway appliances?

Capacity Planning

Work with your capacity planning teams to ensure you're ready for the service mesh.

- [ ] The overhead of the service mesh can vary, but we typically see ~10% overhead, with some applications seeing as much as 30% depending on use cases and workloads. In our experience, existing systems tend to be overprovisioned to the extent that the mesh infrastructure can be added without meaningful changes to resource planning in the short to medium term.

Operations

Work with the operations team to prepare them for incoming infrastructure changes.

- [ ] Start to familiarize them with the service mesh and the capabilities it brings if they were not part of the buying decision.
- [ ] Begin education and training with them, the earlier the better.

Observability and Monitoring

Work with your observability and monitoring teams to prepare them for incoming infrastructure changes.

- [ ] Determine how you'll integrate the mesh's metrics with the existing infrastructure.
- [ ] Ensure you have capacity for the additional metrics the mesh will produce.
- [ ] Evaluate log levels and the resulting log volume produced by the mesh. Verbose logging in the mesh can produce a lot of data!

Platform

Prepare your larger platform team for the incoming infrastructure changes.

- [ ] Get every team member hands-on with your chosen mesh solution.
- [ ] Begin education and training for the platform team ASAP.
- [ ] As a goal, we recommend that a handful of platform team members engage in the underlying OSS projects. This will increase organizational familiarity, confidence, and ability to operate with those technologies.
- [ ] Develop the tenancy model for your system:
  - [ ] Do teams own namespaces? Whole clusters?
  - [ ] How does that map to the mesh?
  - [ ] Will you share ingress gateways or give an ingress gateway per team? We recommend a dedicated ingress gateway per team to start with.

Initial Onboarding

Once your teams are prepared and ready to start implementation, it's time to start the initial phase of adoption.

- [ ] Bucket your applications by criticality, runtime requirements, frameworks, and protocols.
  - [ ] Determine the order in which you'll attack the buckets. We recommend starting with simpler applications that have low criticality and more relaxed runtime requirements—e.g., non-PCI or with loose latency requirements.
    - In the organizations we work with, this group often includes the first Kubernetes services being developed.
    - If your first bucket contains a large group of applications, we recommend hand-selecting an initial subset—between three to five teams—to work with closely and directly.
- [ ] Begin to roll out the mesh one bucket at a time:
  - [ ] Work closely with your initial teams to develop tools, practices, process, and expertise for this class of applications.
    - [ ] Ingress gateway strategy: shared or dedicated to the team?
      - Decide based on criticality and production experience; favor dedicated gateways until you're very confident.
      - Highly critical applications should almost always get a dedicated gateway.
    - [ ] CI/CD changes:
      - If the application team will be authoring mesh configuration, that configuration should be deployed by the same continuous deployment system that rolls out their application
    - [ ] Understand any application changes that may be required:
      - See Istio's documented pod requirements.
      - Do you need to change the application's port labels, or turn off TLS in the application to allow the mesh to do it?
      - How do we deploy the sidecar itself? Do they opt in? Opt out?
      - For this set of apps, are there any systemic changes that need to be made—e.g., exempt database traffic for the time being?
    - [ ] Deploy dashboards for the application based on mesh metrics.
  - [ ] Execute the mesh onboarding. This will usually take a few deployment cycles, as you want to gather information and expertise before, for example, requiring mTLS everywhere. The major steps for each application are:
    - [ ] Start with PERMISSIVE mTLS for the application.
      - This will ensure non-mesh applications calling this application do not break.
    - [ ] Configure gateway routing:
      - If you decide to use dedicated gateways, deploy the gateway instances themselves.
    - [ ] Add sidecar proxies to the application instances (enable injection).
    - [ ] Add a DestinationRule requiring mesh mTLS.
      - This ensures applications in the mesh are using mTLS even if the server allows non-mTLS clients as well.
    - [ ] Configure traffic management settings.

- [ ] Configure traffic management settings.
- [ ] Configure rate limiting and authentication policies.
- [ ] Author authorization policies restricting which clients can communicate.
    - These are typically written by the app team.
- [ ] Lock down STRICT mTLS as soon as all clients have upgraded.

- [ ] Then apply those learnings to the entire bucket of apps.
    - [ ] Create a rollout template that encodes the happy path for all applications in that bucket.
    - [ ] Create playbooks for executing the onboarding.

- [ ] Repeat with the next bucket of more critical, higher runtime requirement, “harder” applications, using the previous learnings to make it easier and faster to execute.