Exploring Linkerd as a Service Mesh for Observability, Reliability, and Security

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1 Introduction

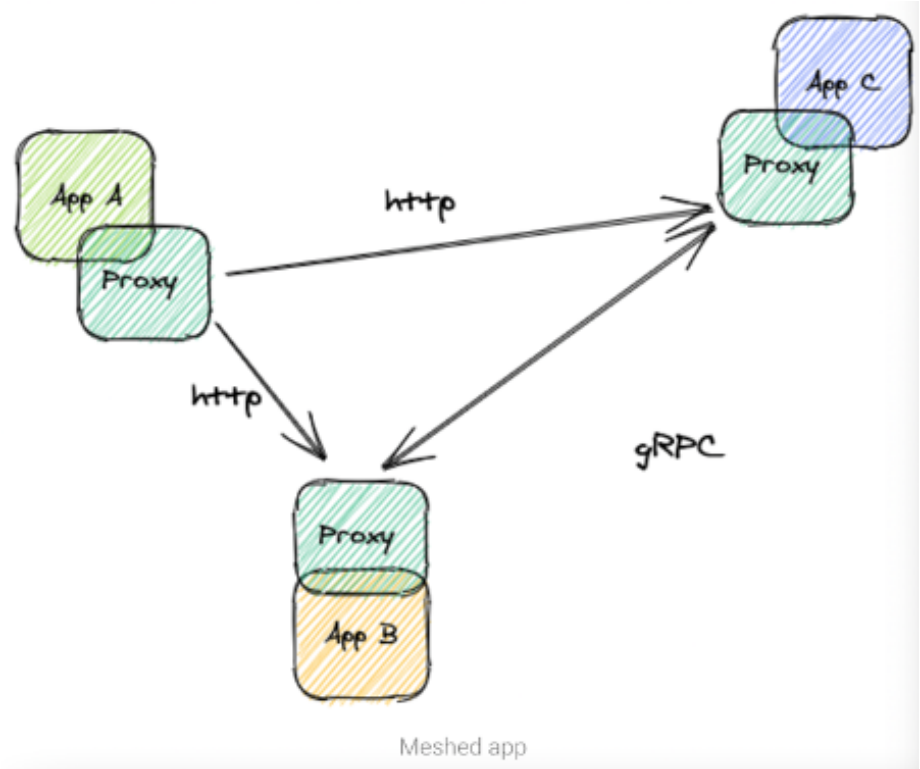
Modern applications are often deployed in a microservices-based architecture where one service might need to interact with many other services to complete its task. This creates an environment where the network can become a map of thousands of different interlinking between the services. This complex network can be difficult to monitor, trace, and debug. A service mesh helps in fixing this problem by acting as a "dedicated infrastructure layer for handling service-to-service communication in order to make it visible, manageable, and controlled"[2]. A service mesh is "a mesh of API proxies that (micro)services can plug into to completely abstract away the network"[5]. By routing traffic transparently through a service mesh, we are able to not only reduce the complexity of the network but also add valuable features such as observability (monitoring), reliability (tolerance and fail-over), and security (TLS encryption) to our applications. This is highly advantageous as it provides a layer of abstraction above the application layer and allows us to "decouple" the application and network without making any changes to the microservices themselves.

Linkerd is one of the most popular service mesh solution due to its ease of use, open-source nature, and high performance benchmarks against its competitors. Linkerd is "easy to configure because of its simpler architecture and due to the fact that it only requires a single process per node"[1]. It is "dramatically lighter, simpler, and more secure"[11] and runs without the need for any third-party components. There are, however, alternatives to Linkerd and detailed comparisons are made to them further in the essay.

2 Service Mesh Architecture

Service Mesh adds functionality by inserting it at the platform layer of the deployment as opposed to the more traditional application layer. It acts as a dedicated infrastructure layer for the network. A general service mesh is made up of at least three components: Proxy, Data Plane, and Control Plane. All three components together offer insight into network traffic at a much more

granular level and offer a way to control how different parts of an application interact with each other. Doing the same with service to service communications built into the applications themselves can become incredibly complex at scale and hard to observe since the network, having been embedded into the application layer, is no longer fully transparent.



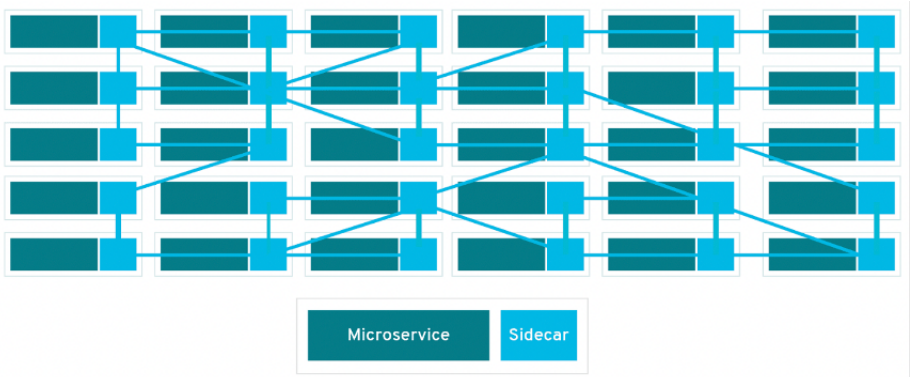
Source: [7]

By abstracting the networking layer to another infrastructure layer a service mesh can offer not just network transparency but also higher security and better load performance by routing requests away from unavailable nodes and towards those that have lesser load.

2.1 Proxy

At its core, a service mesh is built on the idea of "service linking" involving a network of proxies. These proxies are Layer 7 TCP proxies[6] that act as both forward and reverse proxies. Layer 7 is the Application layer in the OSI model which "refers to the underlying protocol that an application uses, such as how a web server uses HTTP to bundle a web page"[15]. As a result, the proxy can make routing decisions based on any detail of a message such as source and destination IP address, SSL handshake metadata, HTTP metadata, etc. In

service mesh terms the proxies are often referred to as sidecars, "since they run alongside each service, rather than within them"[9].



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2.2 Data Plane

These proxies relay calls to each other from their respective services thereby creating a mesh network. This mesh network is known as the data plane. With each proxy transparently intercepting calls to and from their service they're able to extract metrics and apply policy-level changes at the infrastructure layer. This helps in providing not just a more secure foundation for deployments but also provides greater visibility into the network.

2.3 Control Plane

The control plane is a collection of APIs and tools that provide a centralized source for interacting with the data plane. They also provide a centralized source for user interaction and contain a dashboard for the administrator to monitor and interact with. The control plane is also responsible for sending out commands (via APIs or gRPC calls) to the data plane to prepare and setup TLS certificates, metrics aggregation, and policies among other things.[6]

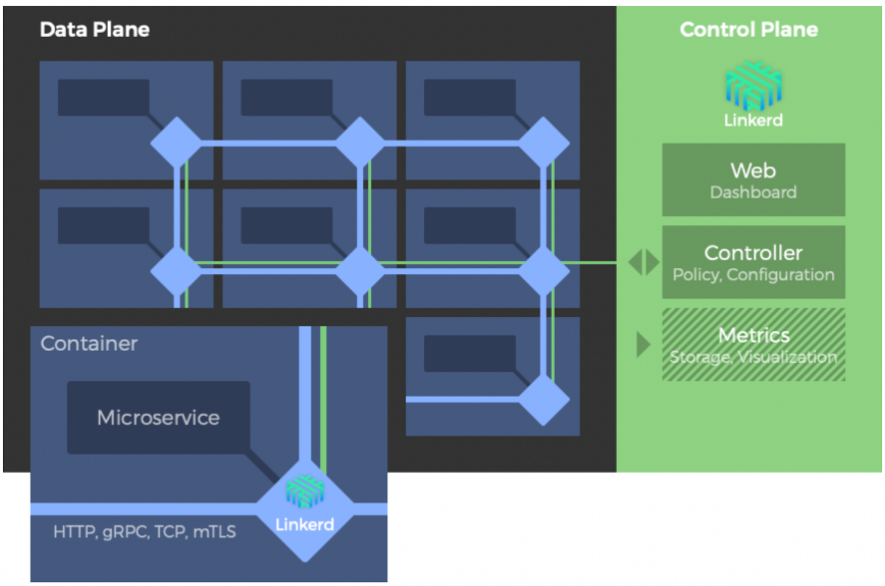
3 Introduction to Linkerd

Linkerd is among the most popular open-source service mesh technologies available today. It is open-source and developed primarily by Buoyant. Linkerd works by installing a set of "ultralight, transparent proxies"[10] along-with each application instance. The proxies handle all traffic between the services and because they're transparent they are able to access network metrics and telemetry data from across the network. This design lets Linkerd ensure they are able to

"measure and manipulate traffic to and from your service without introducing excessive latency"[10].

3.1 Architecture

On a high level the Linkerd architecture looks the same as any service mesh architecture. Linkerd deployed on Kubernetes sits inside its own cluster with its proxy deployed on each pod. The proxies then communicate with each other to create the data plane and are informed or manipulated by the control plane as shown below.

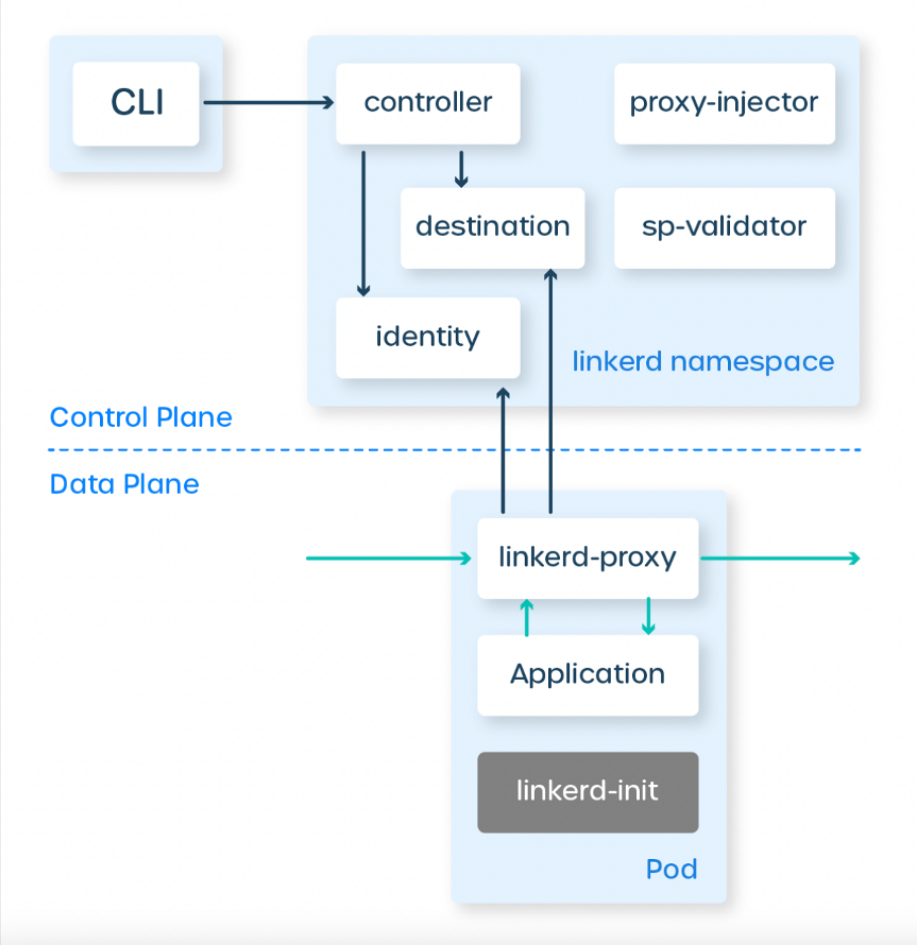


A typical Linkerd deployment on Kubernetes. The control plane consists of a controller, a metrics and a web component. The data plane consists of Linkerd proxies.

Source: [8]

In case of Linkerd the control plane includes a main controller component, a web component that provides access to the dashboard, and a metrics component containing instances of Prometheus and Grafana. The control plane also includes components for service discovery, identity (certificate authority), and public-api for web and CLI endpoints. With the help of these components, the control plane is able to manipulate the Linkerd2-proxy installations across the network for its needs. The control plane components are the ones responsible for implementing retries, adding mutual TLS, and performing request load balancing. The data plane, by contrast, is a collection of all the individual Linkerd2-proxy next to each application instance. The blue boxes in the diagram represent the Kubernetes pod boundaries showing how the proxy runs

inside the pod itself. This is a representative logical diagram. Deployed in production, the control plane may expand to three or five instances and the data plane to hundreds or thousands.



Source: [6]

In the figure above you can see the several different components of Linkerd's control plane along with a single Linkerd2-proxy sitting alongside a service instance. Many service mesh use Envoy as a proxy layer but Linkerd uses a small-scale micro-proxy written in Rust called Linkerd2-proxy which it has built from the ground up to be "highly-performant and requiring low footprint"[11]. Linkerd2-proxy is designed to be secure, lightweight, and to consume a lot fewer resources than something like Envoy which can have a bigger footprint on resource usage.[11]

3.2 Observability

Since Linkerd, and most service mesh, are designed to be used in conjunction with microservice architecture, they work best when deployed on something like Kubernetes as they can rely heavily on the underlying Kubernetes constructs. Combined with Layer 7 transparency where proxies can see and act on request metadata, this helps Linkerd easily see the health of the app by surfacing metrics by namespace, deployments, pods, and even clusters. Linkerd is able to tap into inter-app communication and allow a visual look into the live request-response metadata of each network call. This increased visibility in turn increases observability at a level that is not possible when the service-to-service communication is baked into the application layer. Having abstracted network as a layer complex activities like tracing network calls and diagnosis of network issues becomes a trivial task.

3.3 Reliability

Linkerd also uses native Kubernetes constructs to improve reliability and performance benefits for services. Services can offload routing and DNS strategies to the proxy layers and benefit from smarter routing decisions so that requests don't end up at failed instances. Linkerd proxy offers better performance by simply monitoring which nodes receive traffic frequently and route requests away from them towards less busy nodes. They do this using an implementation of an exponentially weighted moving average algorithm. Since the Linkerd2-proxy layer acts as both a forward and reverse proxy it can also be configured to allow retries timeouts and provide "latency-aware Layer 7 load balancing for HTTP traffic and Layer 4 load balancing for non-HTTP traffic" [5].

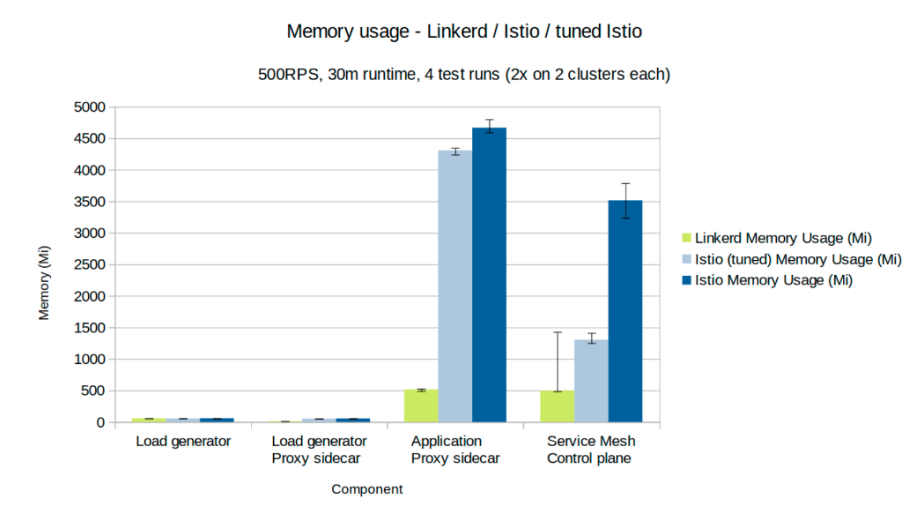
3.4 Security

Linkerd offers zero-trust protection on Kubernetes environments. Zero-trust protection is based on the idea that services should be continuously authenticated and not trusted by default. Most simply, this is done using two-way certificate authentication. Linkerd simplifies this by transparently and automatically enabling mutual TLS (mTLS) between all services. The idea behind the design is to have always-on security by default with low configuration overhead. Since security is often made resilient by being in the open for thorough testing, Linkerd has also participated in independent security audits so as to ensure growing trust in the service and it has been found that "the Linkerd codebase and implementation are very robust from a security standpoint"[3].

3.5 Competitive Advantage

These days, the service mesh space is buzzing with names such as Linkerd, Istio, and Consul. However, Linkerd emerges in many ways as not just a competitive candidate but a leading one. Unlike its competitors, Linkerd can be

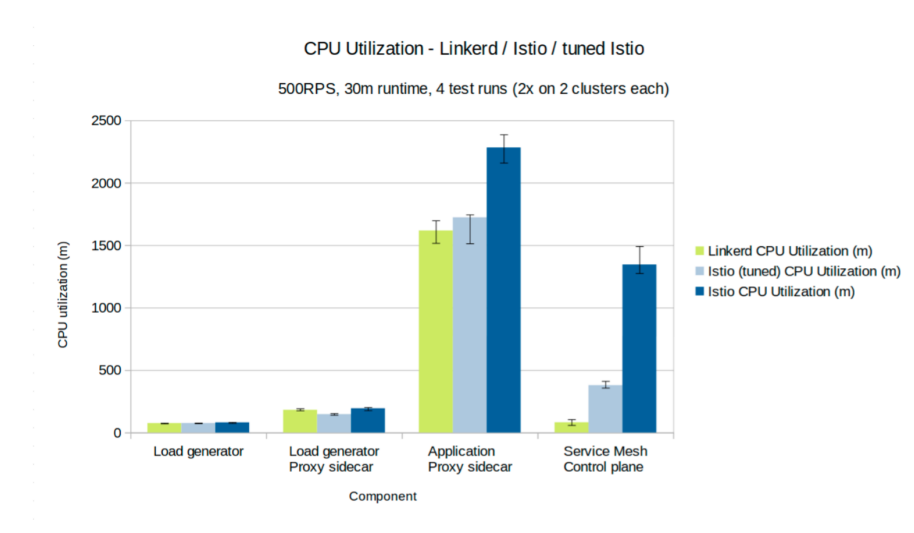
deployed as a sidecar on individual hosts making it an economical and flexible choice as shown in the diagrams below[11]. Linkerd requires no configuration out of the box and is thus also easier to setup compared to its competitors. It comes with support for HTTP/2, gRPC, and other common protocols. It allows mTLS setup throughout and distributes traffic highly intelligently using modern load-balancing algorithms. It provides "dynamic request routing and distributed tracing"[4] to allow for easier debugging of root cause of issues. Being an open-source software itself, it provides built-in integration with other open-source projects such as Prometheus and Grafana for visibility into telemetry and analytics. All these features combined ensure Linkerd provides a high level of resilience at a low resource footprint that offers it a slight competitive advantage over its peers.



Source: [13]

4 Drawbacks of Service Mesh

Being built on the microservice architecture, a service mesh operates best in an environment where service-to-service calls are pre-optimized. Often, this implies a Kubernetes environment where the underlying constructs are used widely in the implementation. Despite the strong coupling, a dedicated infrastructure layer that covers all network communication can seem an "invasive implementation"[10]. They can be a complex technology that is difficult to retrofit into environments that are not microservice or Kubernetes oriented. A monolith with some microservices can certainly work with a service mesh but it may not offer the same level of visibility and reliability in a monolith as it would in a microservice model. As a result, it's not a viable solution in some contexts and is best applied to newly developed microservice based applications.



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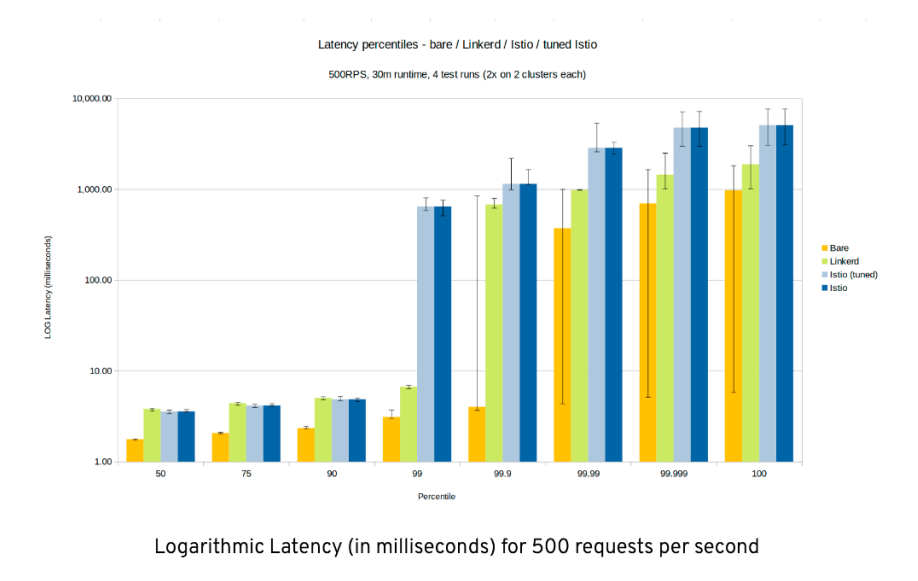
The architecture of the service mesh itself has some direct implications. Adding a proxy to every pod can quickly become a massive increase in resource requirement. All requests to and from one service are routed through its proxy. Heavy use of proxies implies that they should be fast since at least two hops are added to each network call and they need to be small and lightweight in order to not affect performance. Additionally, they can have a considerable impact on application performance as compared to direct calls across the network. As a result, service meshes are often criticized for their poor performance and resource overhead. Thanks however to its extensive focus on simplicity, minimal configuration, and lightweight proxy, Linkerd does well in trying to get close to this bare metal performance.

One of the biggest concerns against service mesh technologies is the added complexity to a deployment. In application landscapes that are constantly evolving, a service mesh can offer overhead that may be too much to handle. Since they come with certain built-in tooling, they offer opinionated solutions that may not exist beforehand in the environment thus leading to more integration and education overhead. If a service mesh fails at any point, it creates additional overhead of debugging the debugger. For many companies the service mesh deployment is a fairly new exercise and time spent on understanding the tooling may take away time from more productive endeavors. As a result, a service mesh can often become difficult to justify for a hybrid, dynamic, and fast-evolving environment.



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5 Benefits of Service Mesh

Despite their drawbacks, service mesh do offer a state-of-the-art solution to make microservice communication resilient. They offer high observability and security across the entire stack and configure the network as a dedicated infrastructure layer. This allows abstracting all network failures and allows for easy debugging in failure or performance issues. It allows for increased visibility into debugging the network layer that may otherwise have been bundled into the application.

As we've observed, service meshes are best used in stand-alone, microservice-based or Kubernetes-forward environments that allow for individual deployments and updates. Each new service that is added to such an environment can easily be incorporated into the mesh by simply adding a proxy along the service. Over time the data captured by the service mesh can be applied as policy or service network rules to make the system more efficient and reliable. By providing visibility at the network layer a service mesh can offer insight into routes or ports that may well be closed thereby increasing security of the system. These performance metrics can then offer other ways to further optimize communication channels between microservices.

6 Conclusion

Service meshes offer tracing, intelligent routing, health checks, mTLS, identity, and reliability. The service mesh space is "still nascent enough that codified standards have yet to emerge, but there is enough experience that some best

practices are beginning to become clear"[14]. It is best if a service mesh offers endpoints with similar weight and granularity and provide multi-tenant solutions. If the API endpoints are too non-uniform, then it can result in metrics that are less comparable across the board. As a result, observability may suffer, and the promise of visibility may be lost. Additionally, service meshes suffer if not all the services are part of the mesh. This is one of the biggest reasons they are not as easily adopted in multi-cluster and hybrid environments. Uniformity is also required as they work best in environments that benefit from having a self-contained microservice-based model.

Many applications today are not written in the service-based communication style of independent microservices. Many applications are still monolithic behemoths that are slowly migrating towards a more micro-service-based style. As a result, it's possible that for these types of applications a service mesh can seem like a problem looking for a solution. In fact, using a service mesh in such an environment may not even be suitable. However, there are still immense benefits to adding solutions like Linkerd to the ecosystem as they allow a relatively low footprint entry into the world of service meshes. They can offer a faster and more uniform approach into the world of service-to-service communication between microservices.

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