



Prof. James Mickens

Distributed Systems and Security Expert

PUBLIC REDACTED VERSION

Ex. No.

PXRD010

1:20-cv-03010-APM

1:20-cv-03715-APM

Assignment

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA

UNITED STATES OF AMERICA, *et al.*,

Plaintiffs,

v.

GOOGLE LLC,

Defendant.

Case No. 1:20-cv-03010-APM

HON. AMIT P. MEHTA

STATE OF COLORADO, *et al.*,

Plaintiffs,

v.

GOOGLE LLC,

Defendant.

Case No. 1:20-cv-03715-APM

HON. AMIT P. MEHTA

PLAINTIFFS' REVISED PROPOSED FINAL JUDGMENT

WHEREAS, Plaintiffs United States of America, and the States and Commonwealths of Arkansas, California, Georgia, Florida, Indiana, Kentucky, Louisiana, Michigan, Missouri, Mississippi, Montana, South Carolina, Texas, and Wisconsin, by and through their respective Attorneys General ("Co-Plaintiff States"), filed their Complaint on October 20, 2020, and their Amended Complaint on January 15, 2021;

AND WHEREAS, Plaintiffs Colorado, Nebraska, Arizona, Iowa, New York, North Carolina, Tennessee, Utah, Alaska, Connecticut, Delaware, District of Columbia, Guam, Hawaii, Idaho, Illinois, Kansas, Maine, Maryland, Massachusetts, Minnesota, Nevada, New Hampshire, New Jersey, New Mexico, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Puerto Rico,

Assignment 1: Assess divesting Chrome from a technical perspective

Assignment 2: Assess data sharing and syndication remedies from a technical perspective

Why Distributed Systems?

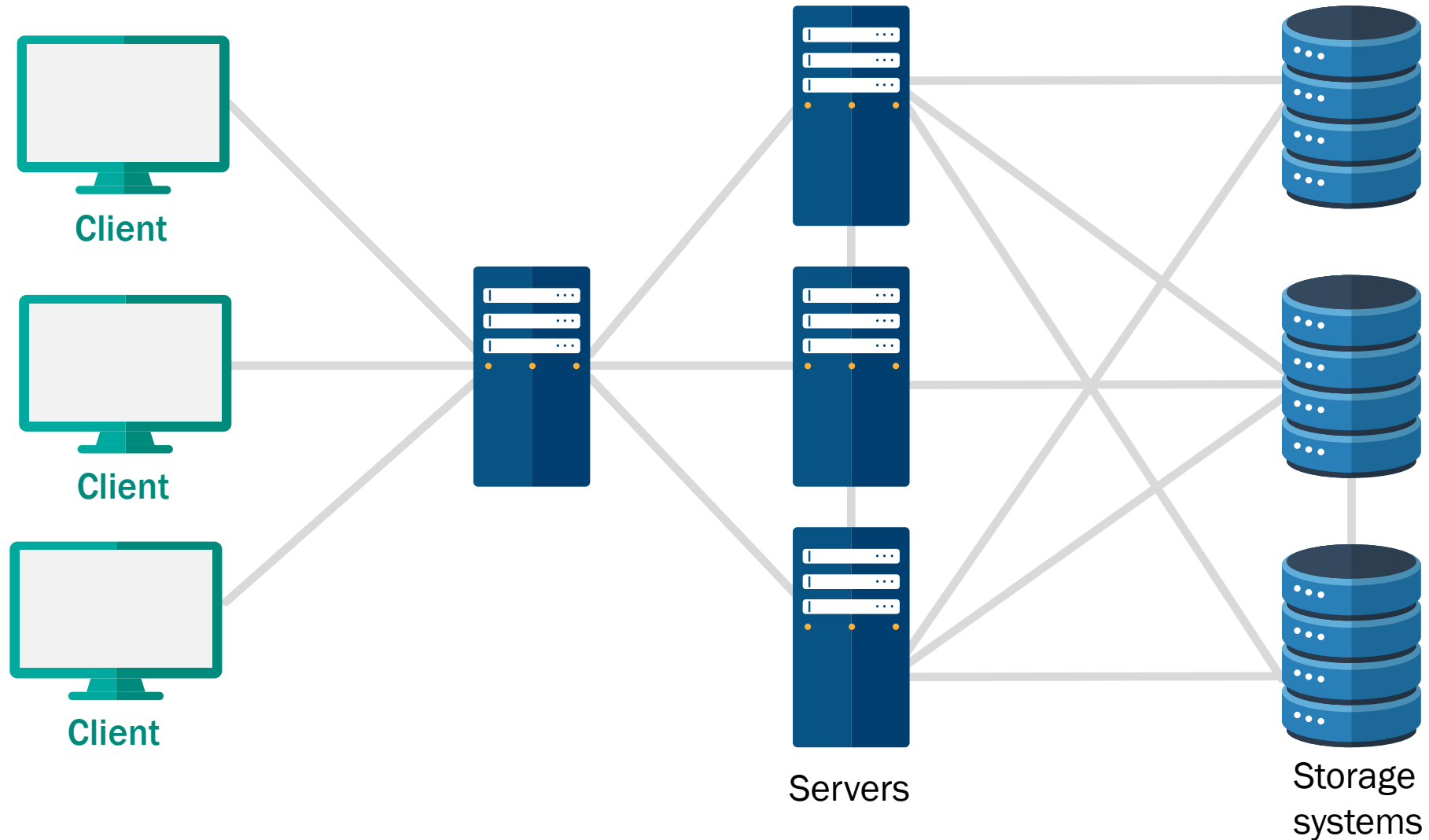
Understanding **distributed systems** is a necessary step in understanding the divestiture, data sharing, and syndication remedies.

Distributed Systems: An Overview



Single Computer

Distributed Systems: An Overview



Key Conclusions

Conclusion 1: From a technical perspective, Chrome divestiture is feasible.

Conclusion 2: From a technical perspective, data sharing and syndication remedies are feasible.

Technical Feasibility



Type of work Google and third parties already do.

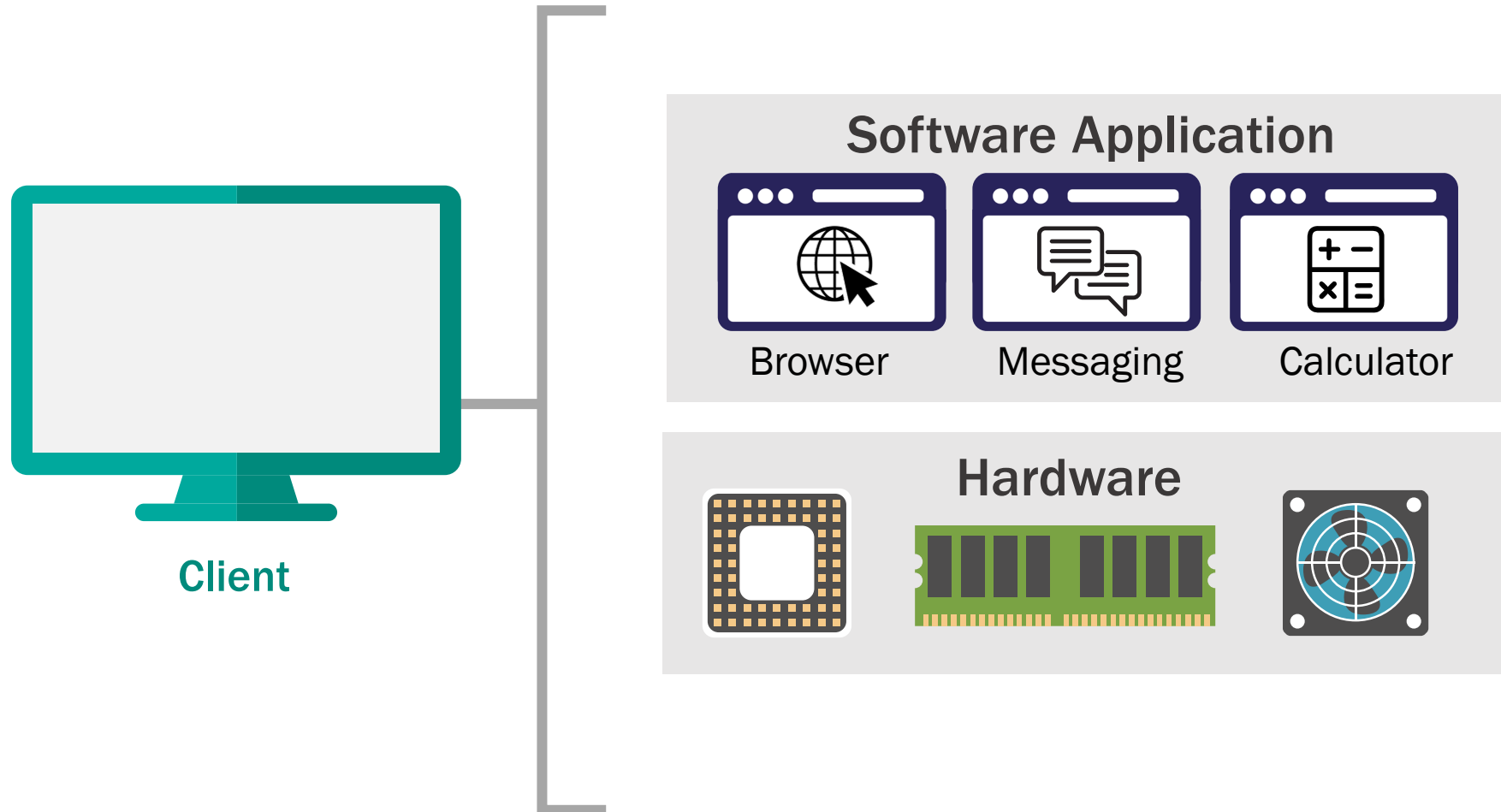


That work is not unduly burdensome.

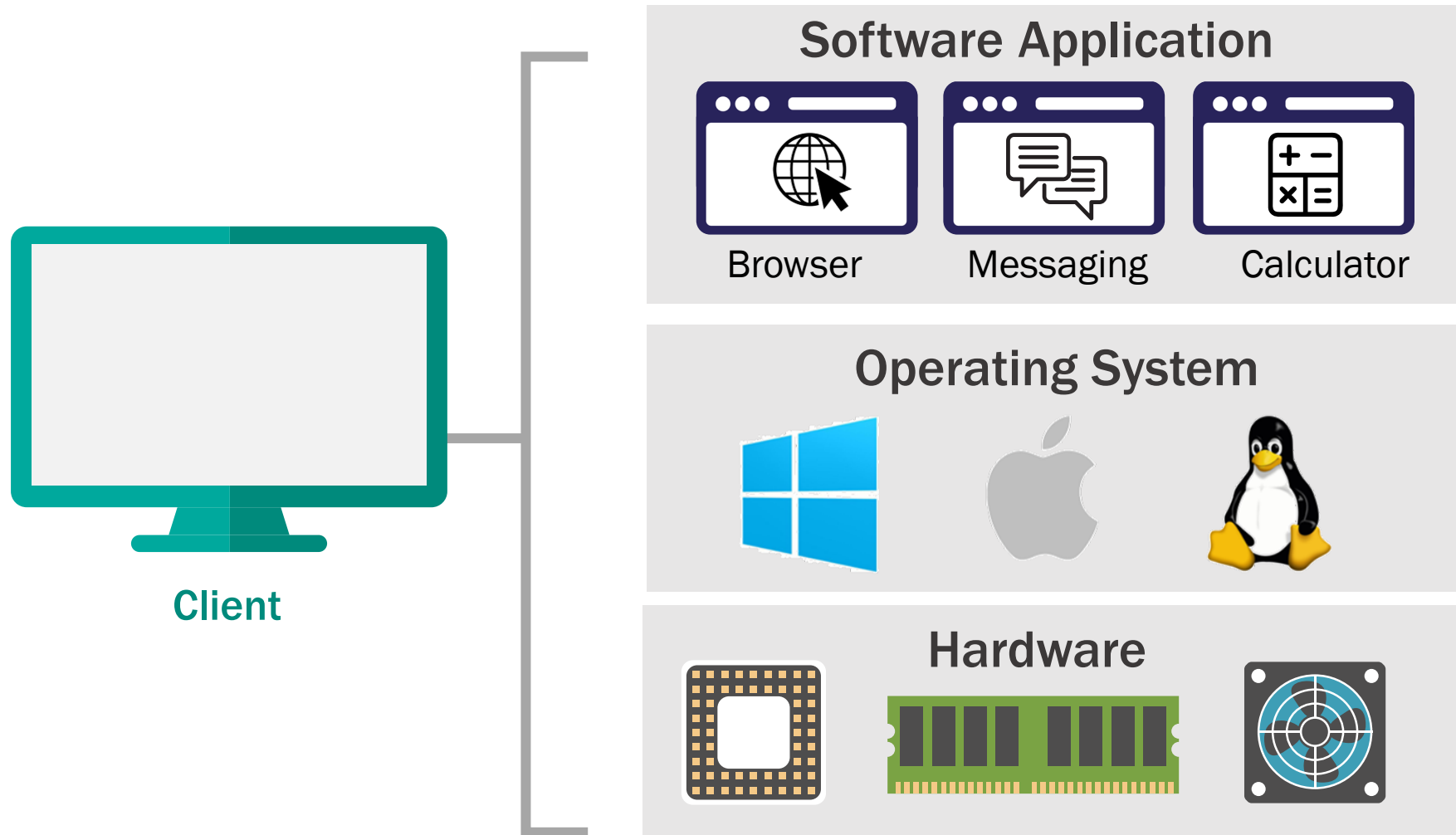


That work can be done in a way that preserves security.

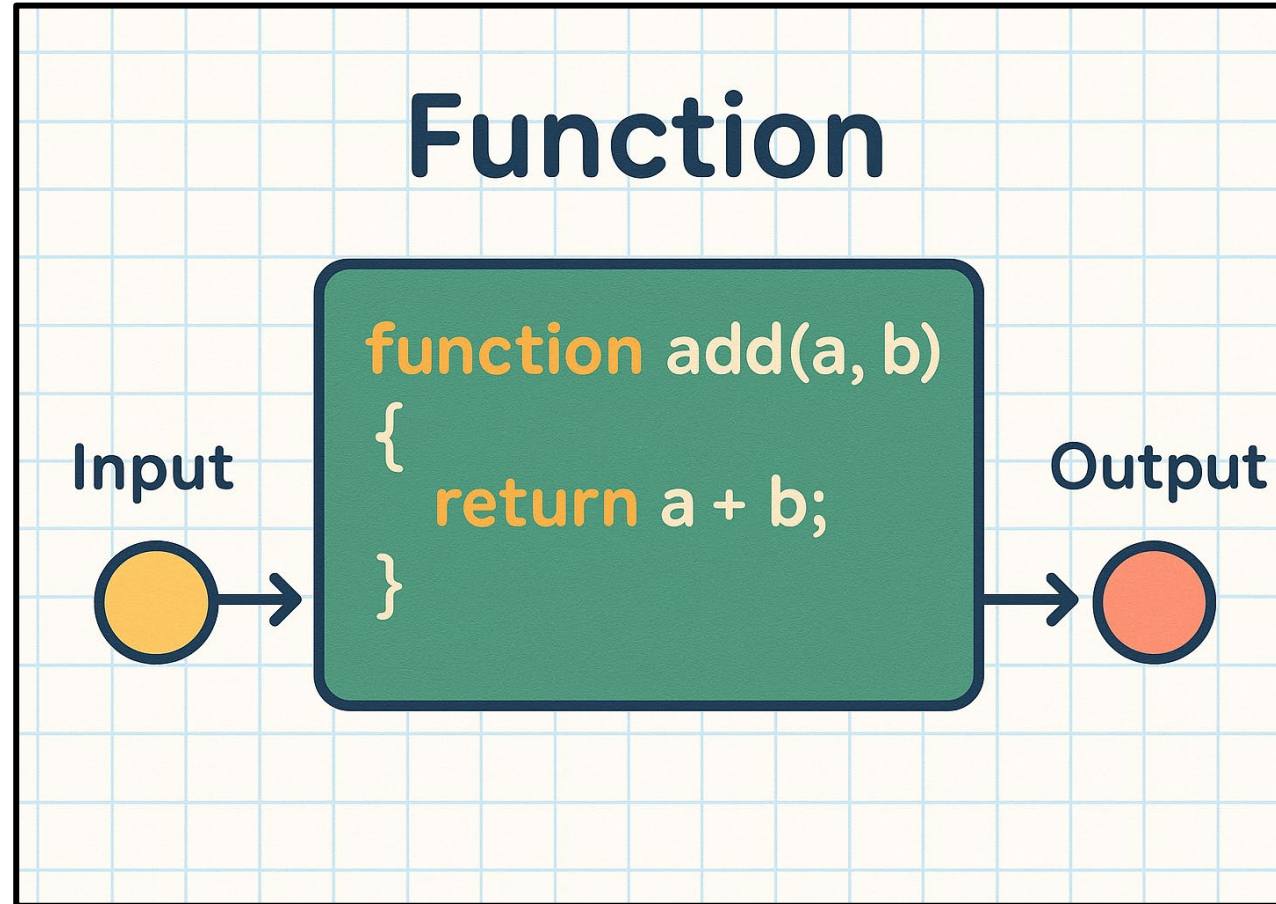
Computers: An Overview



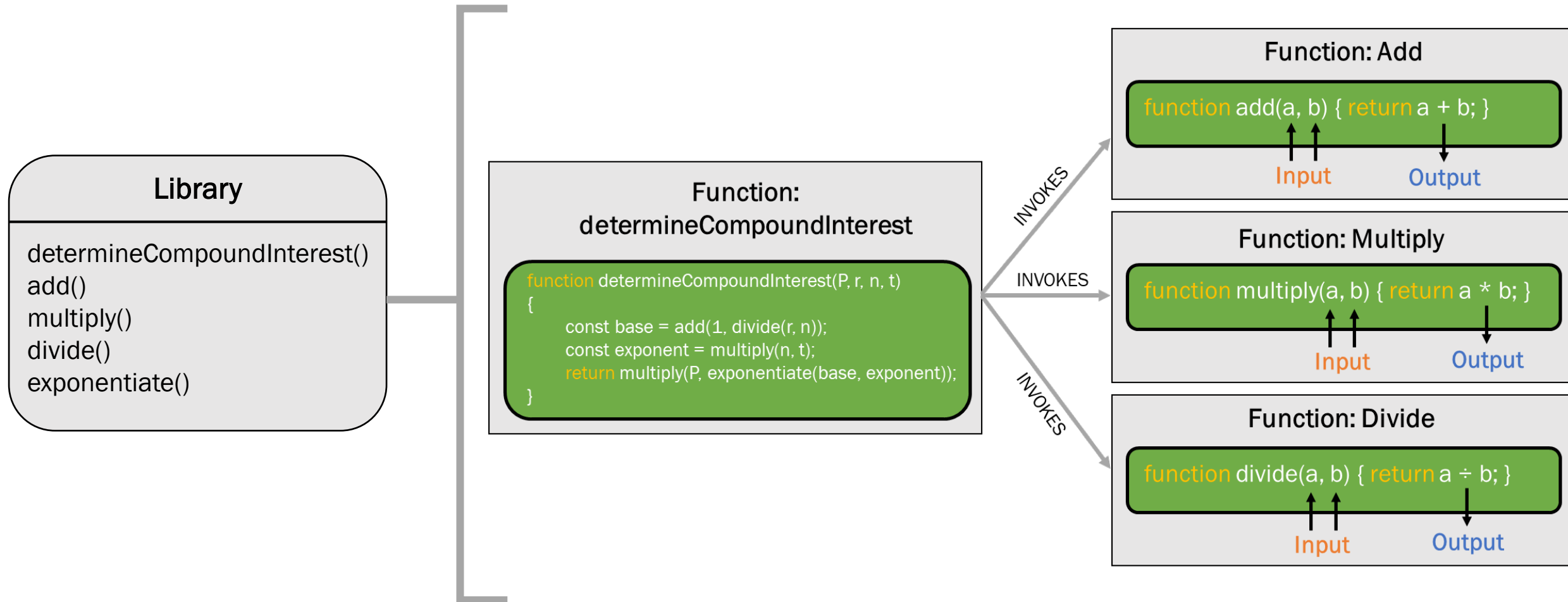
Computers: An Overview



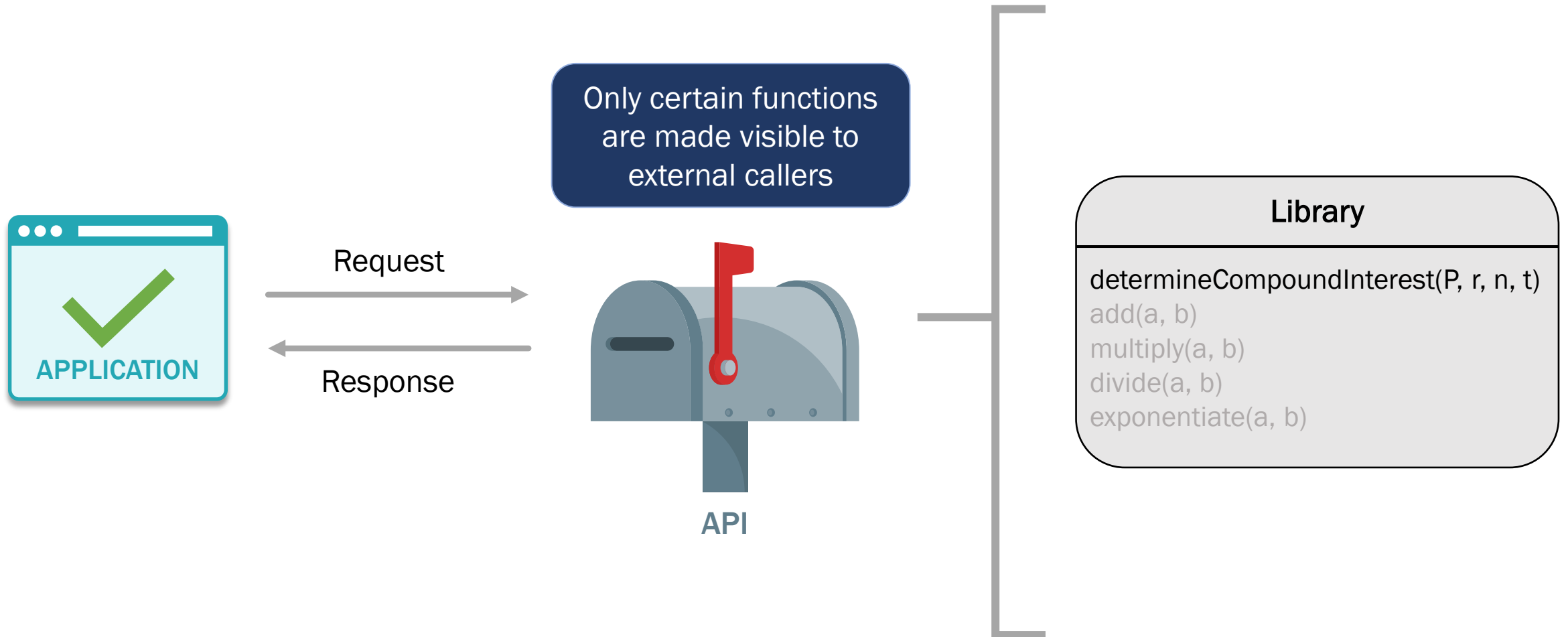
Functions Are Blocks of Code



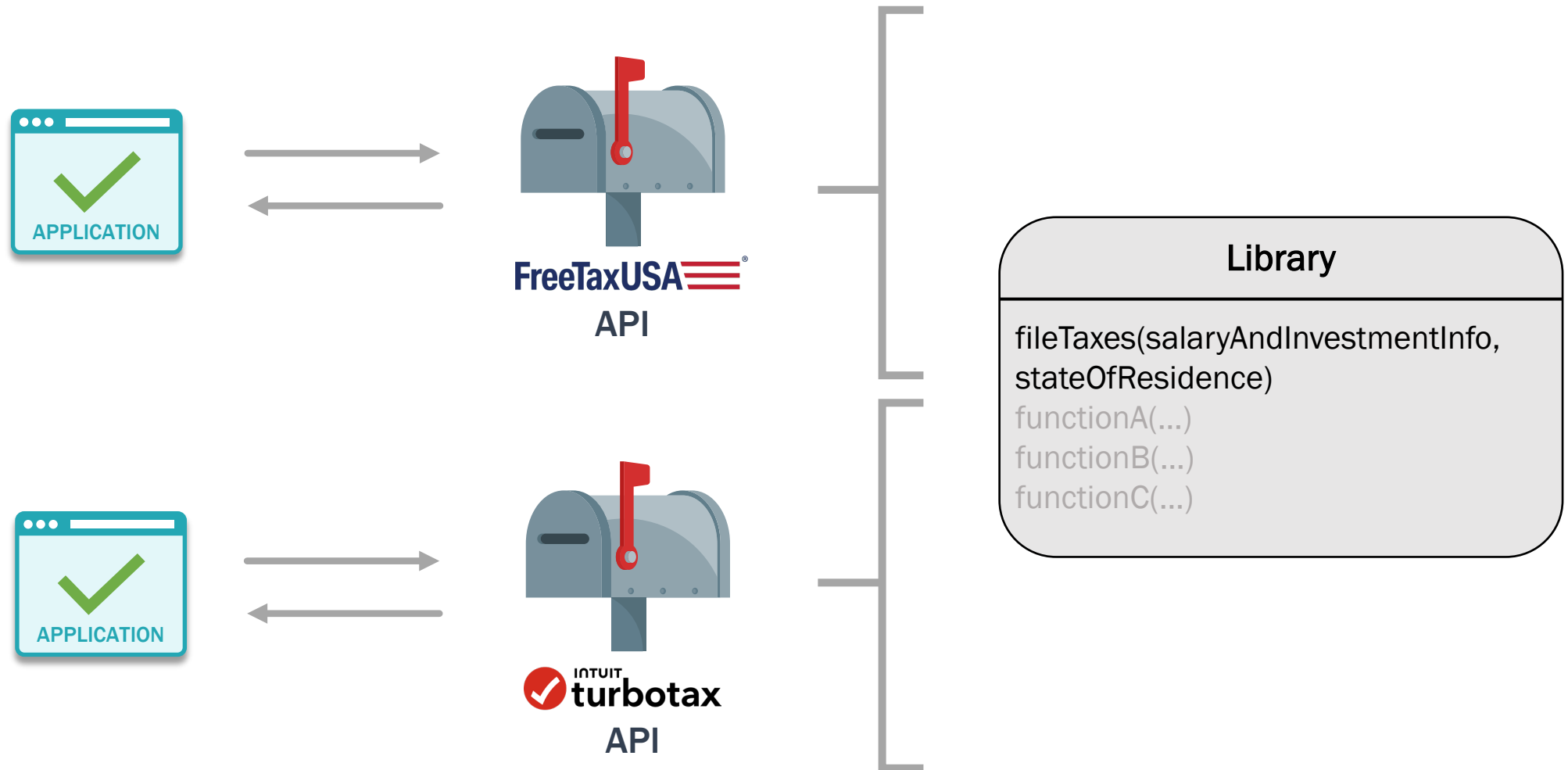
Libraries Are Collections of Functions



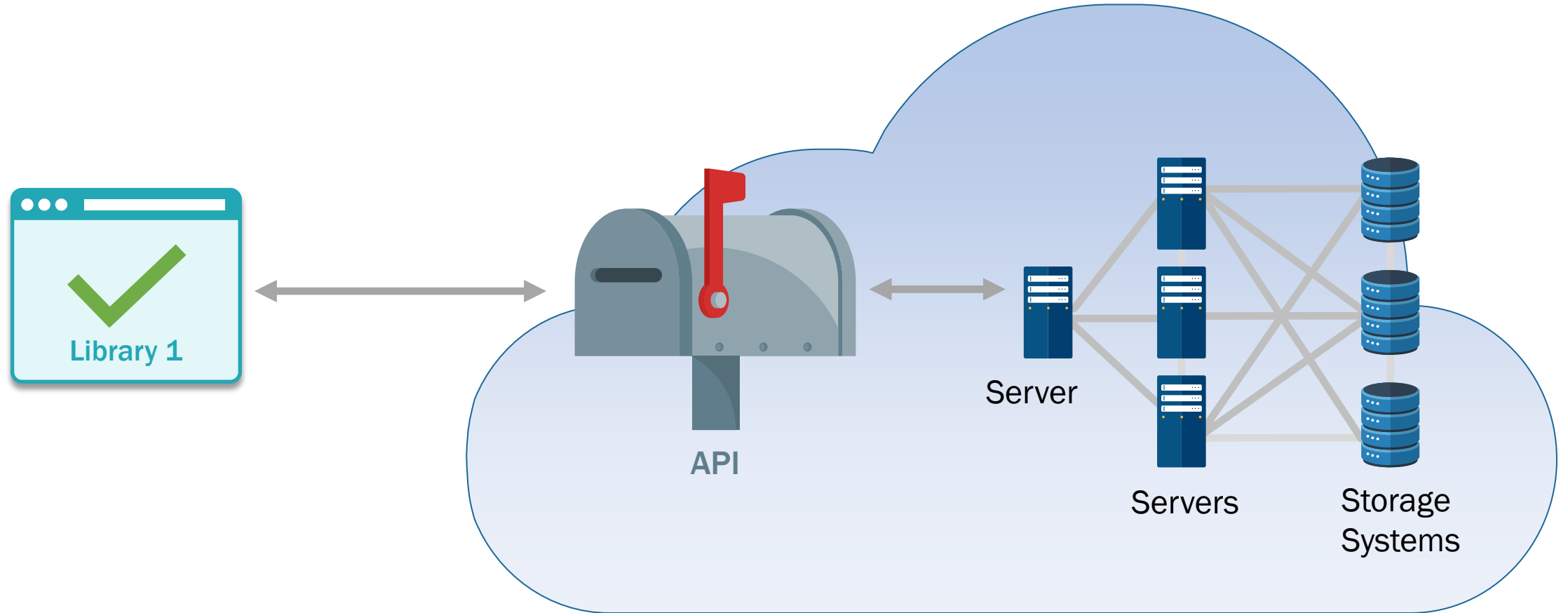
Application Programming Interfaces (APIs) Allow Software Programs to Talk to Each Other



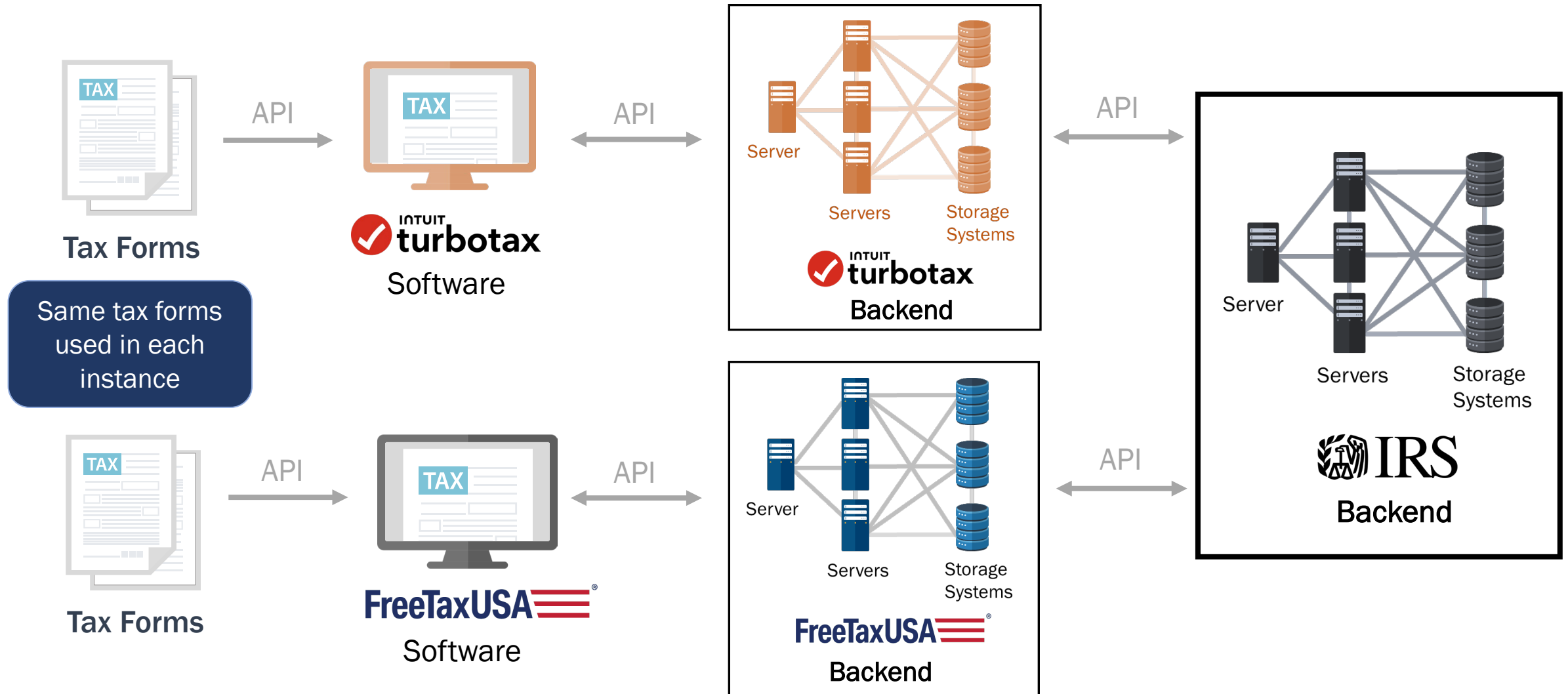
Tax Example: API



Cloud APIs Connect to Code Running in the Cloud



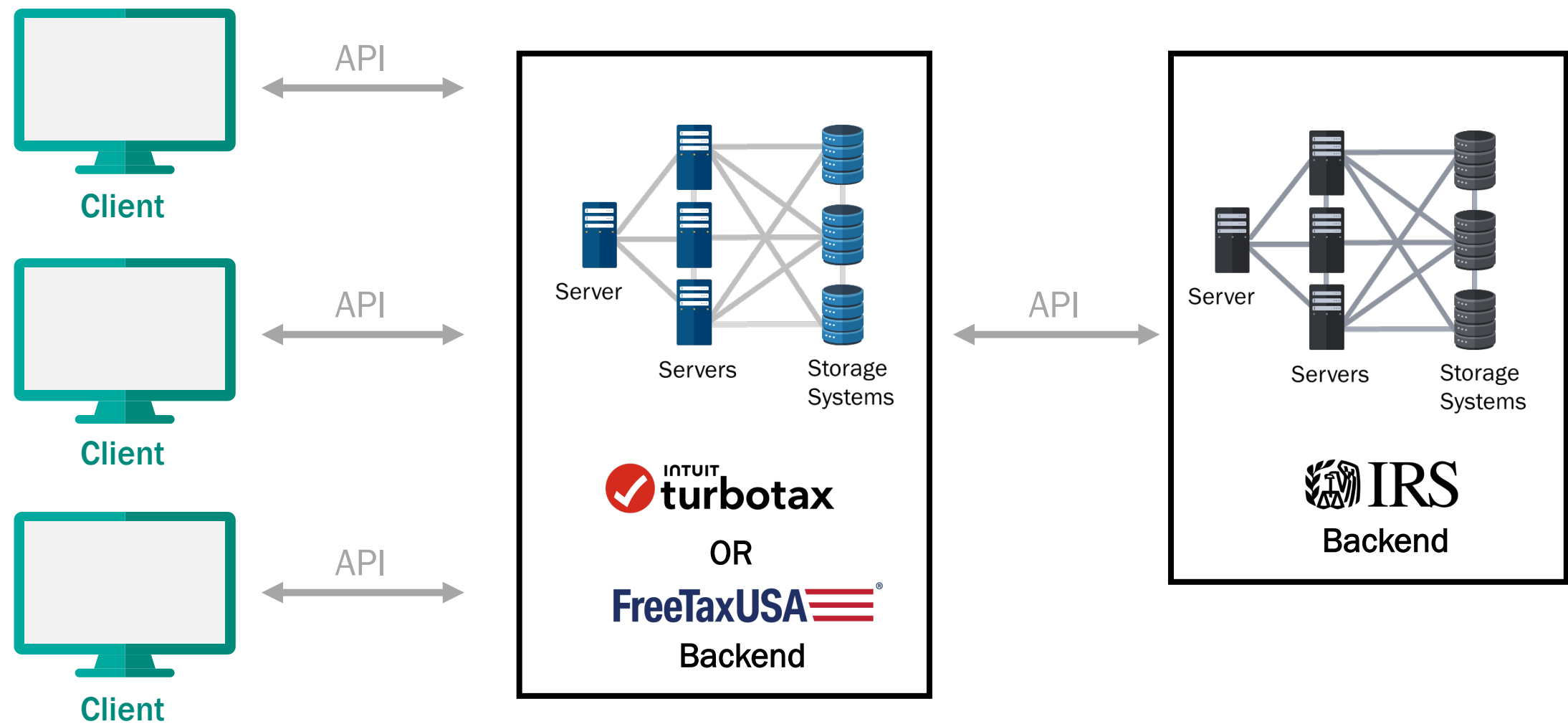
Tax Example: Distributed Systems



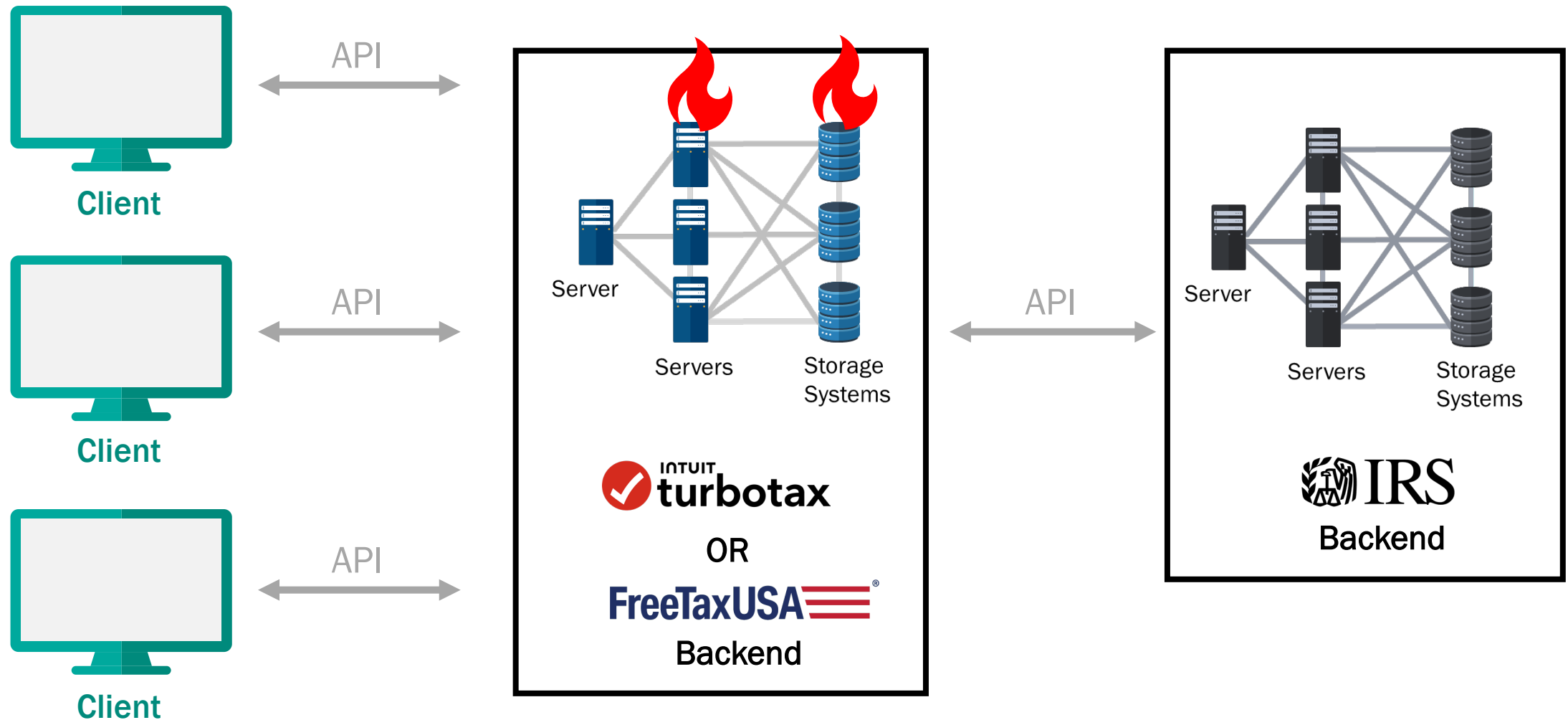
Hardware Infrastructure



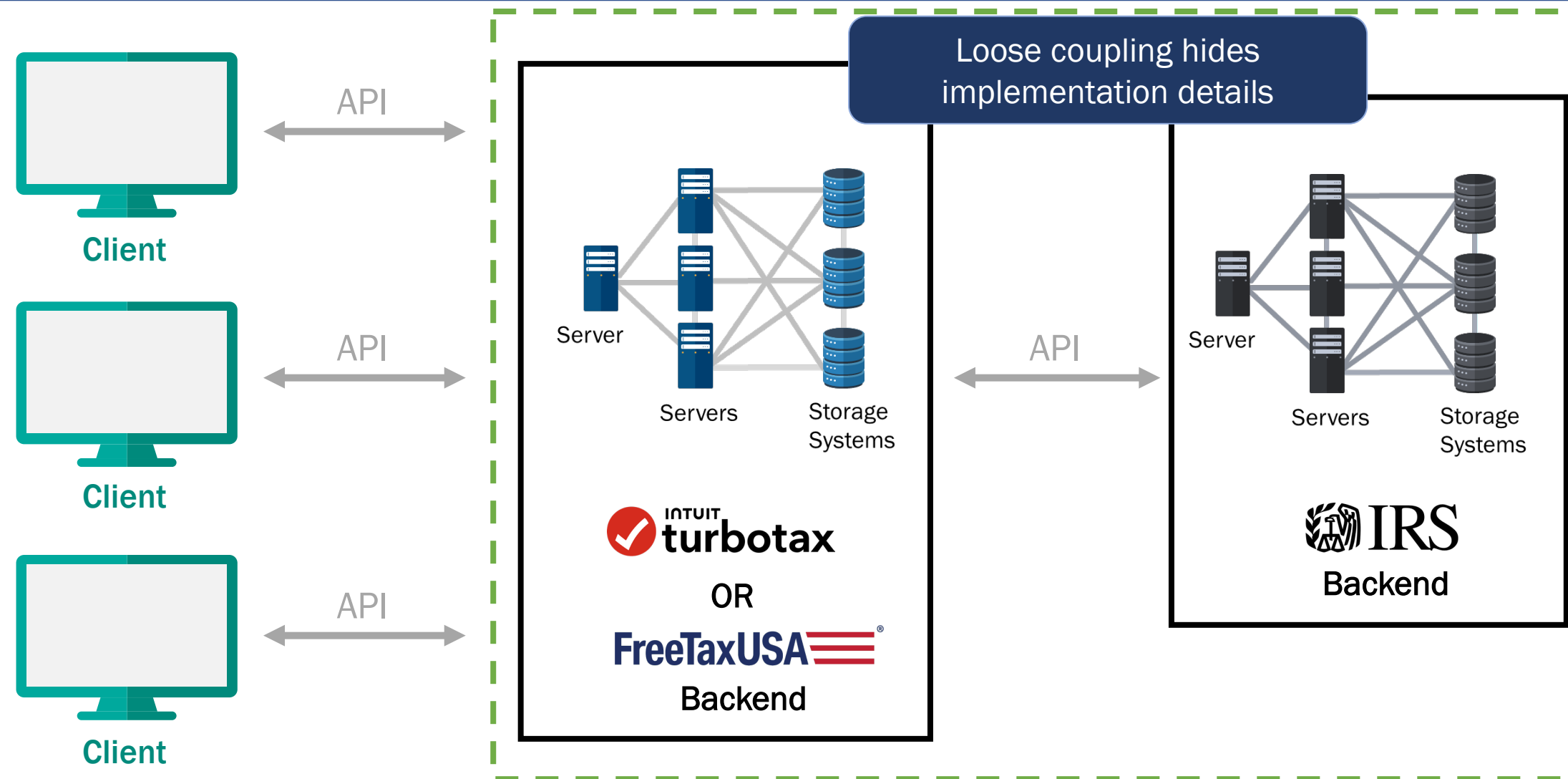
Benefits of Distributed Systems: Scalability and Efficiency



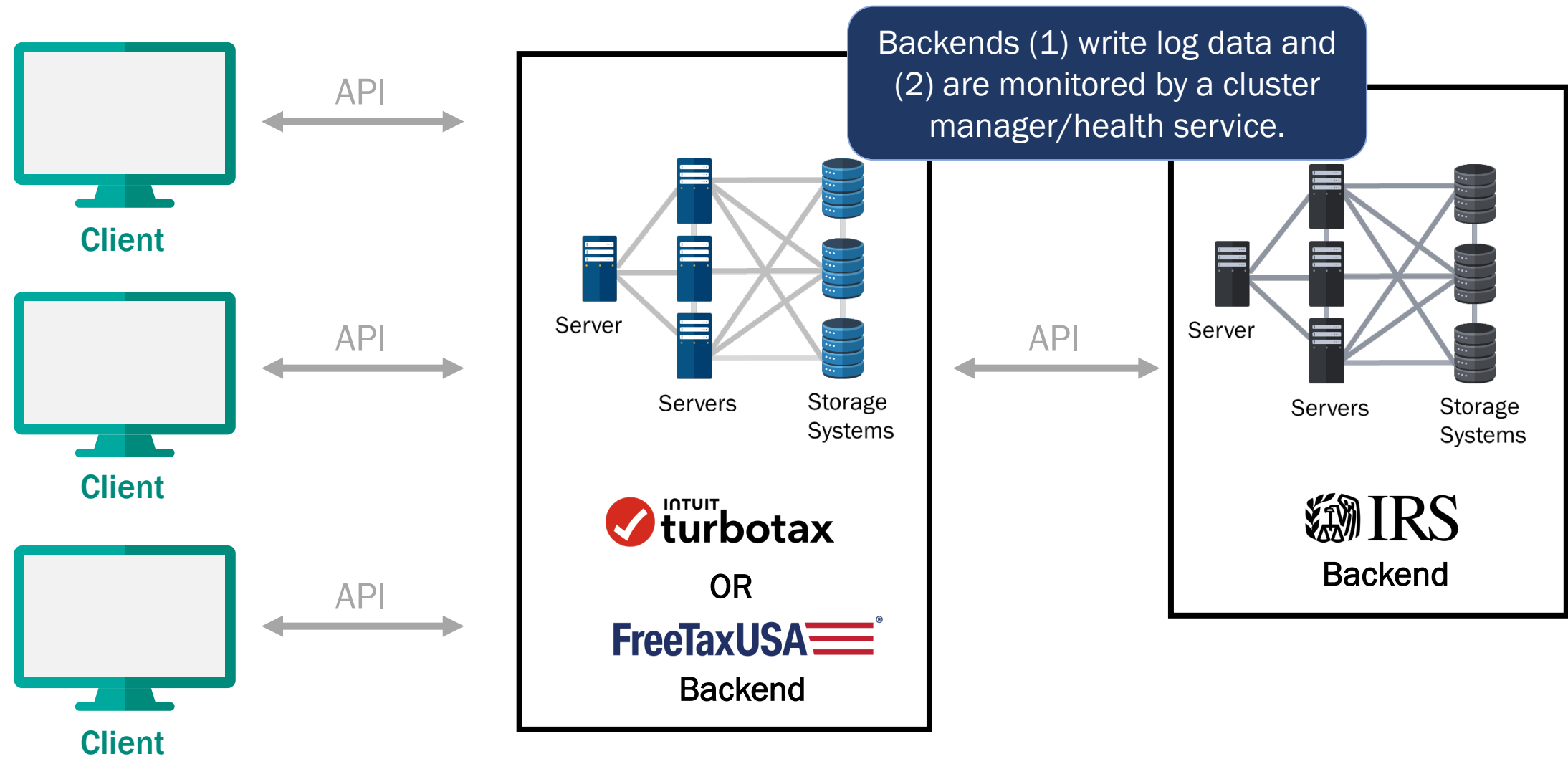
Benefits of Distributed Systems: Reliability



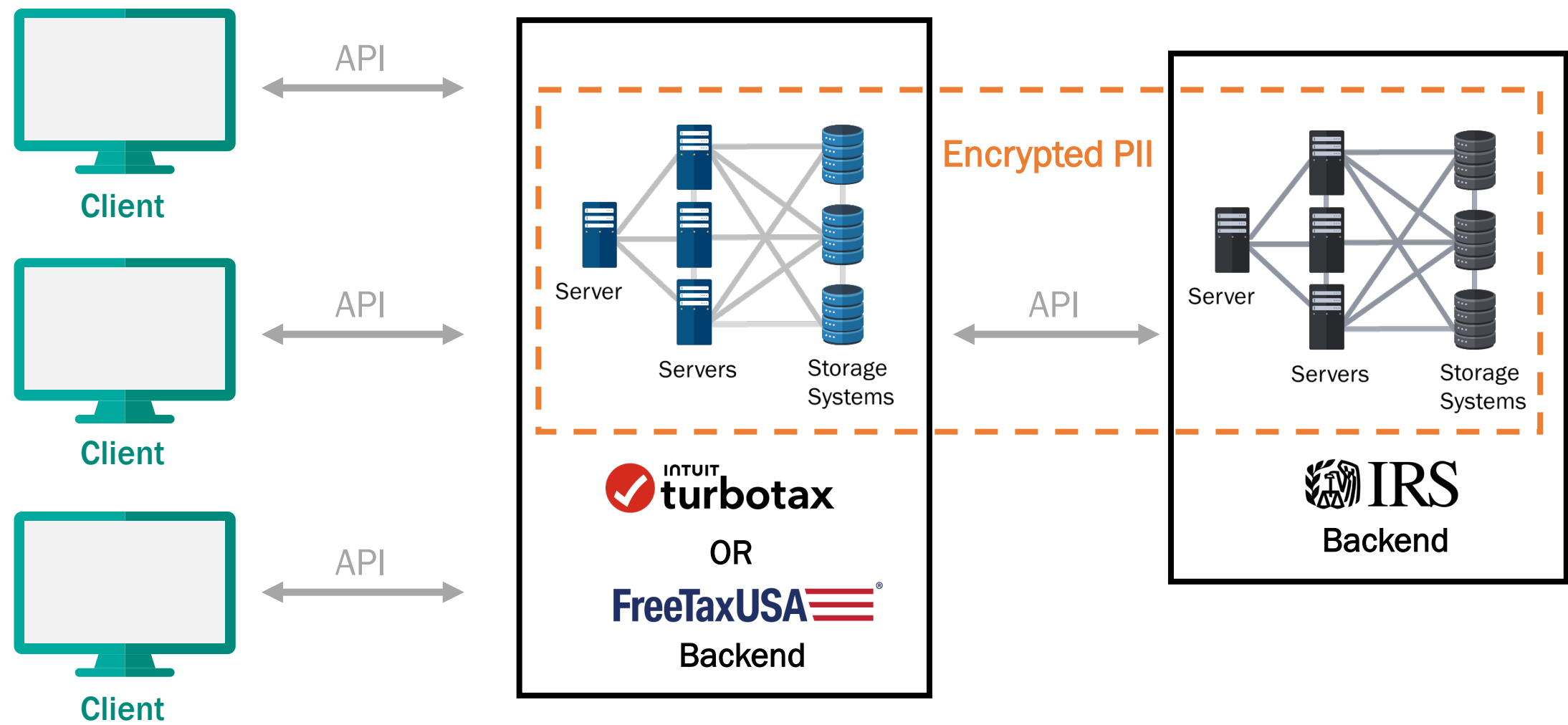
Best Practices with Distributed Systems: Loose Coupling



Best Practices with Distributed Systems: Observability



Best Practices with Distributed Systems: Security

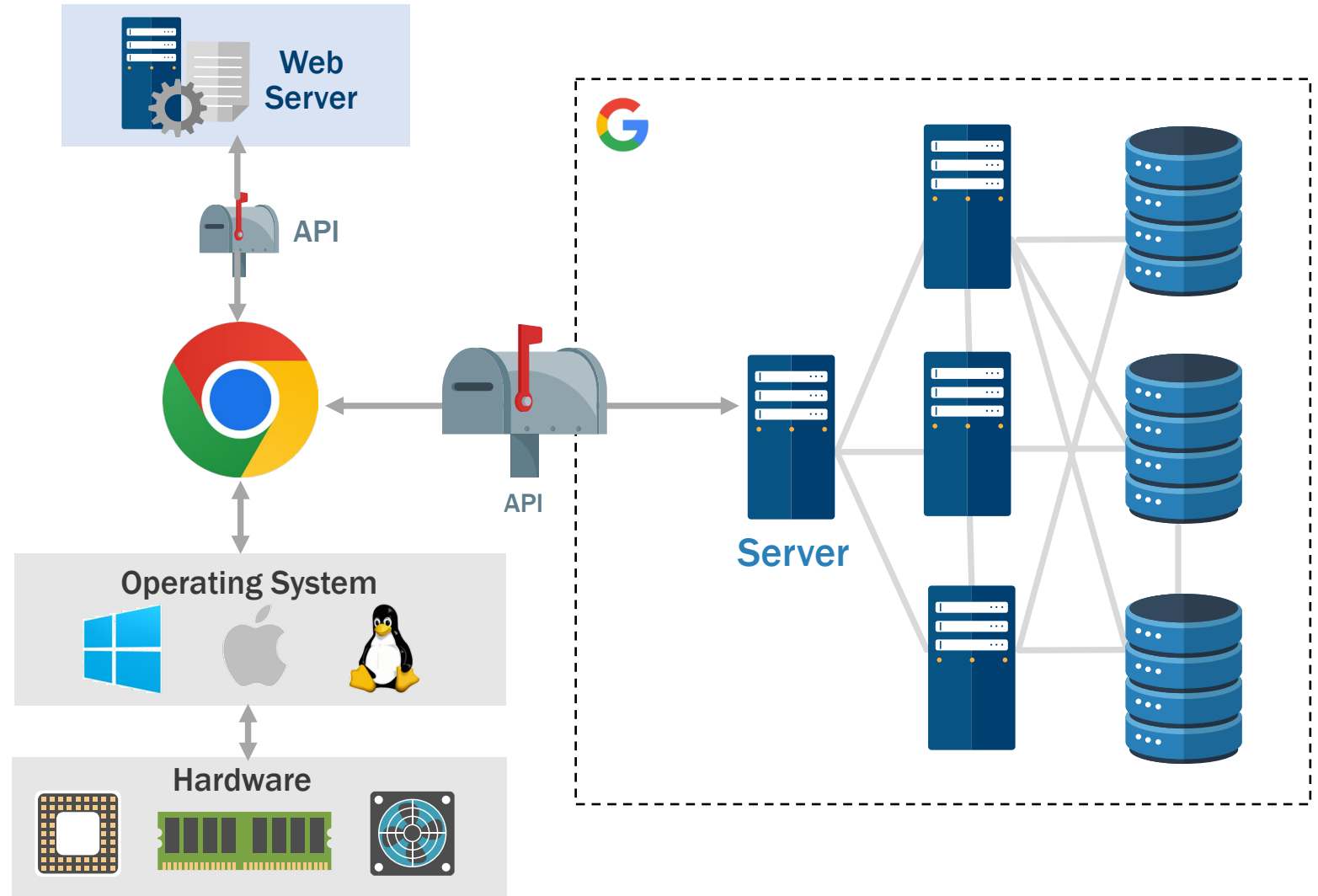


Opinion # 1: Chrome Divestiture is Feasible

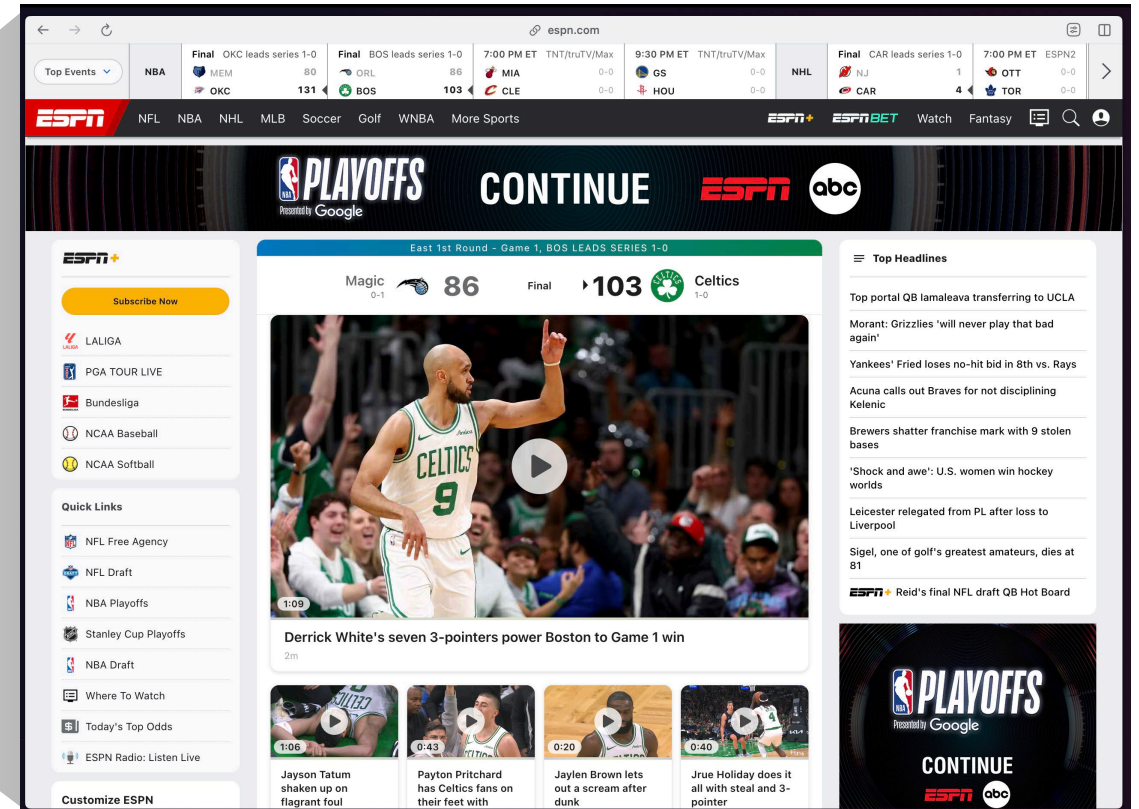
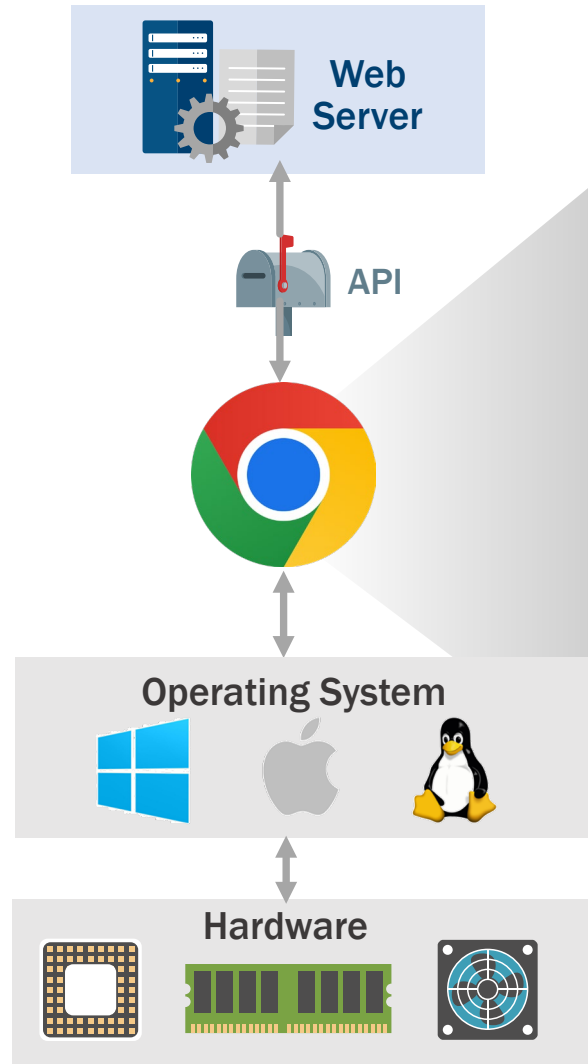
The Chrome browser is not deeply integrated with an underlying operating system.

The Chrome browser is not deeply integrated with Google's back-end services.

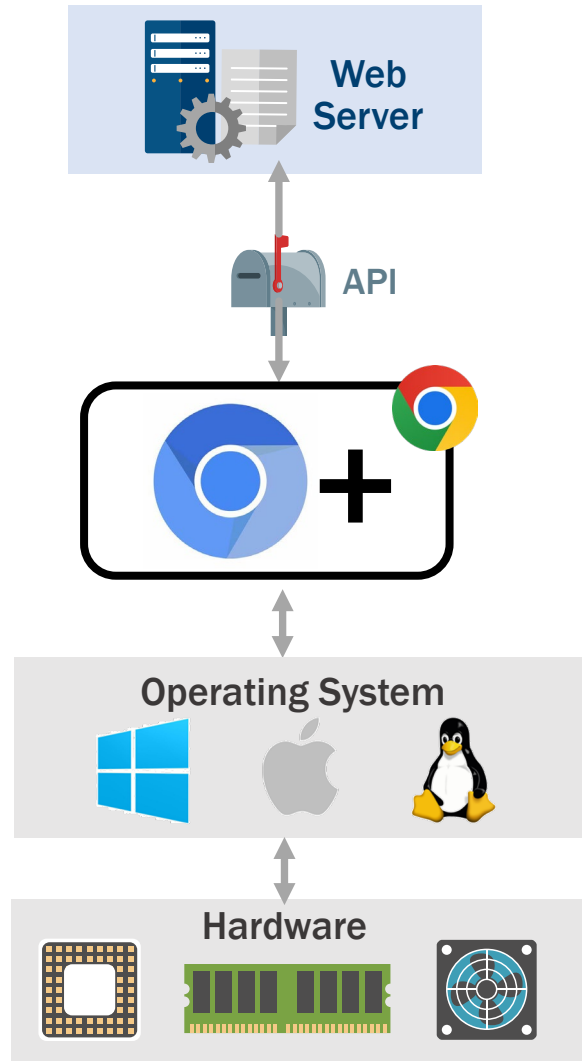
Chrome is A Piece of Client Software



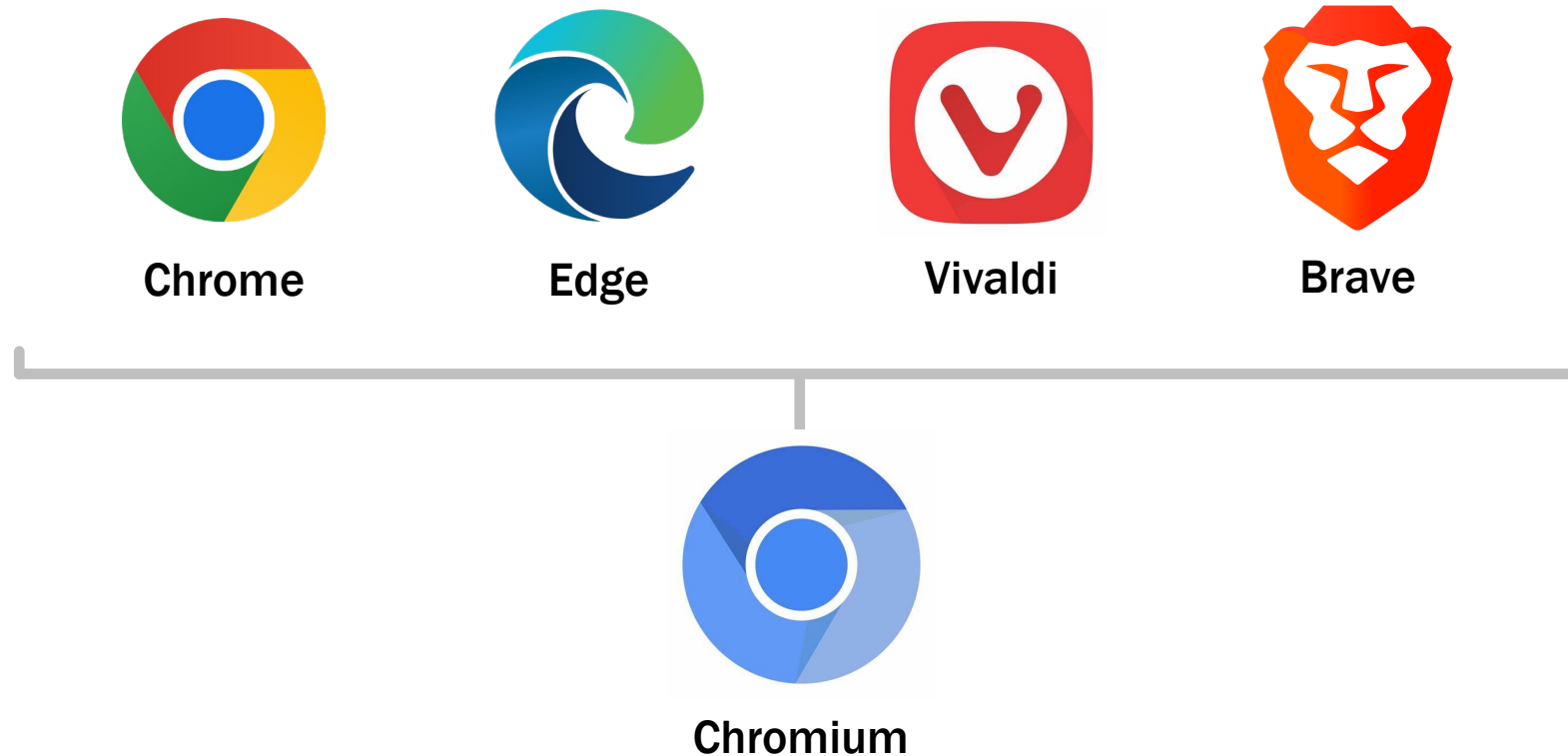
A Browser's Role



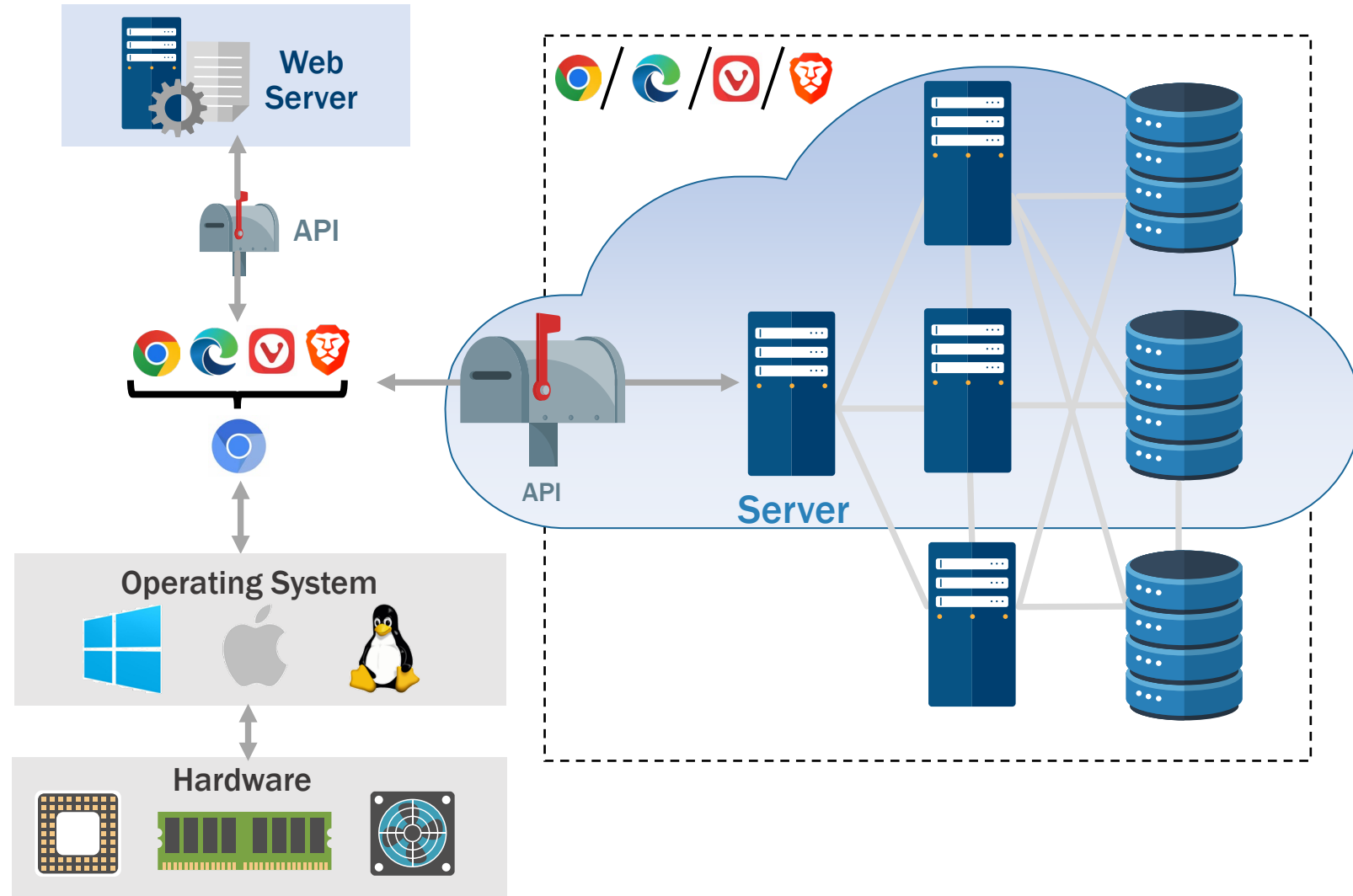
Chrome Is Built on Top of Open-Source Chromium



Other Browsers Are Built on Top of Chromium



Each Chromium-Based Browser Makes Unique Design Decisions



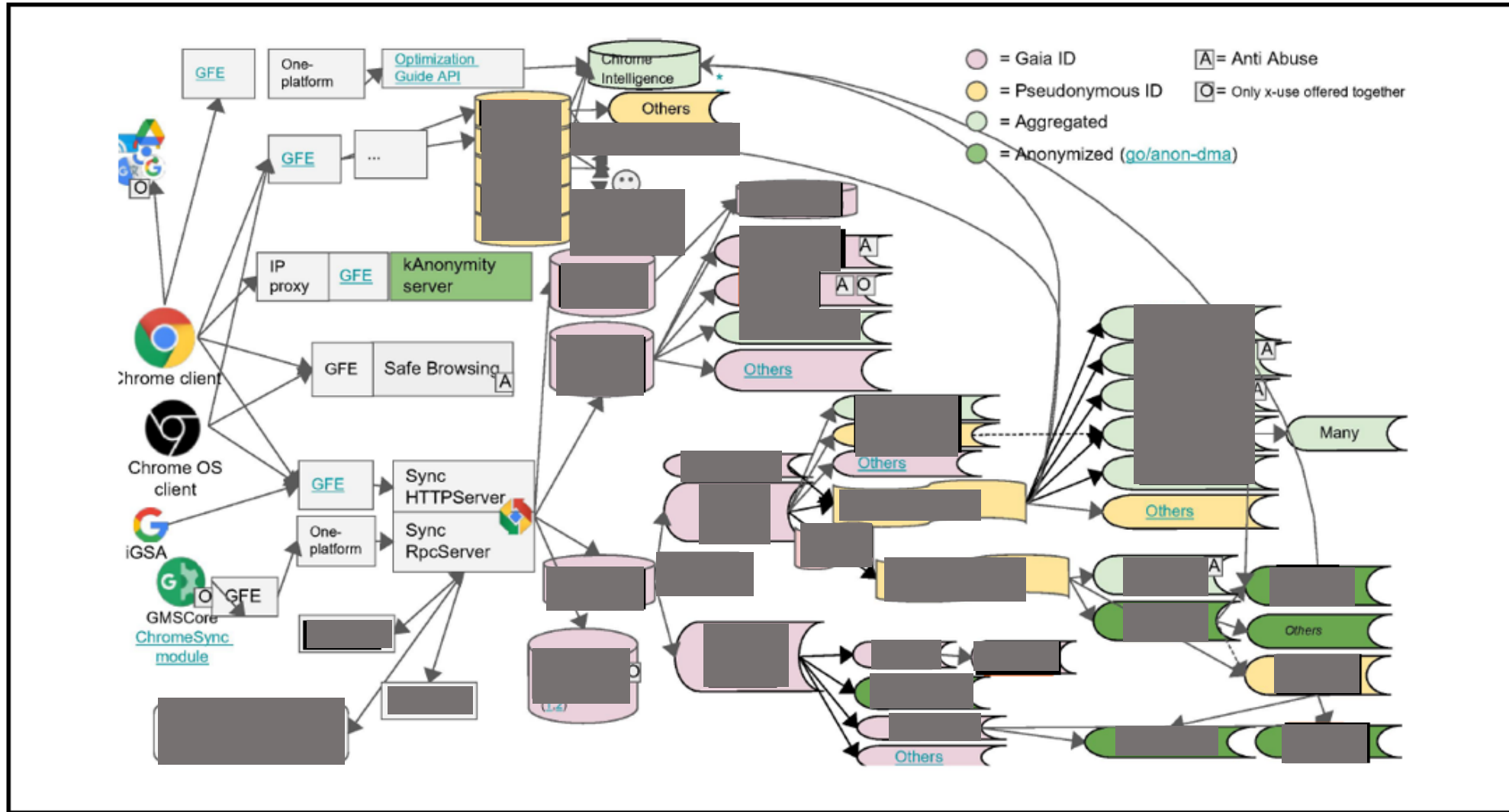
Examples of Google's Backend Services

GAIA API: Authentication service that allows users to log into Chrome.

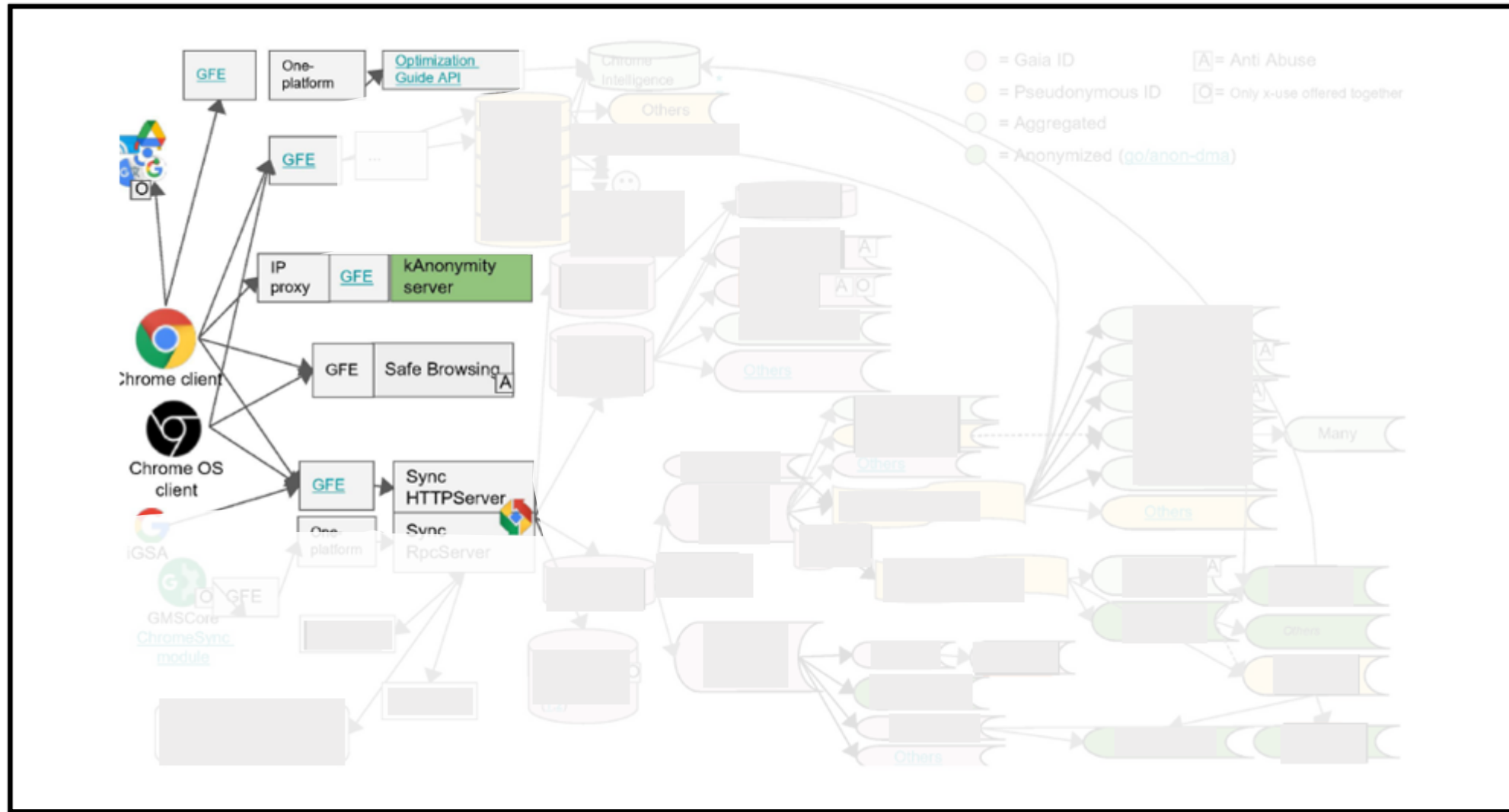
Chrome Sync: Synchronizes Chrome data across multiple signed-in devices.

Safe Browsing API: Analyzes and identifies harmful web pages for the Safe Browsing service.

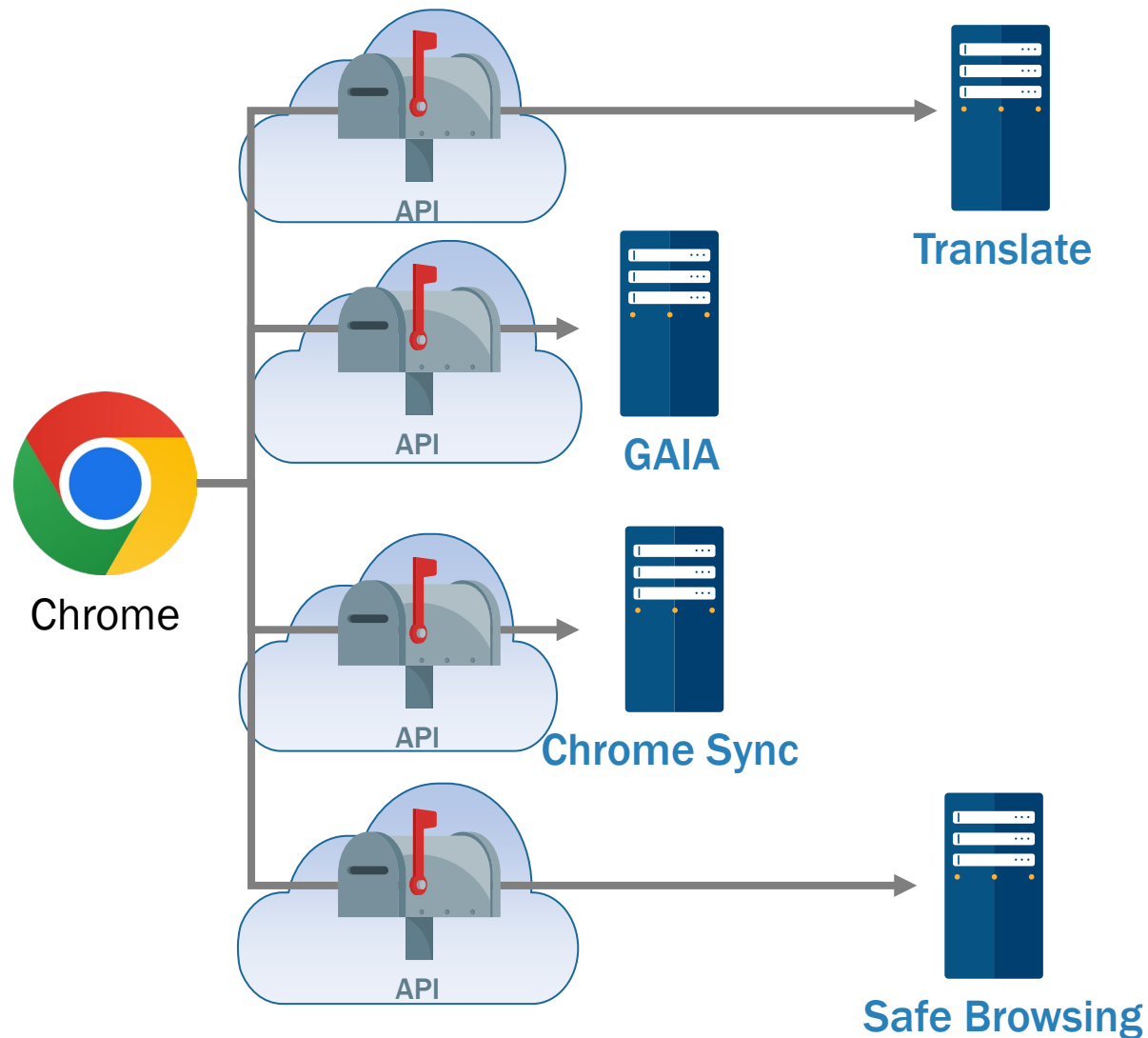
Chrome and Google's Backend



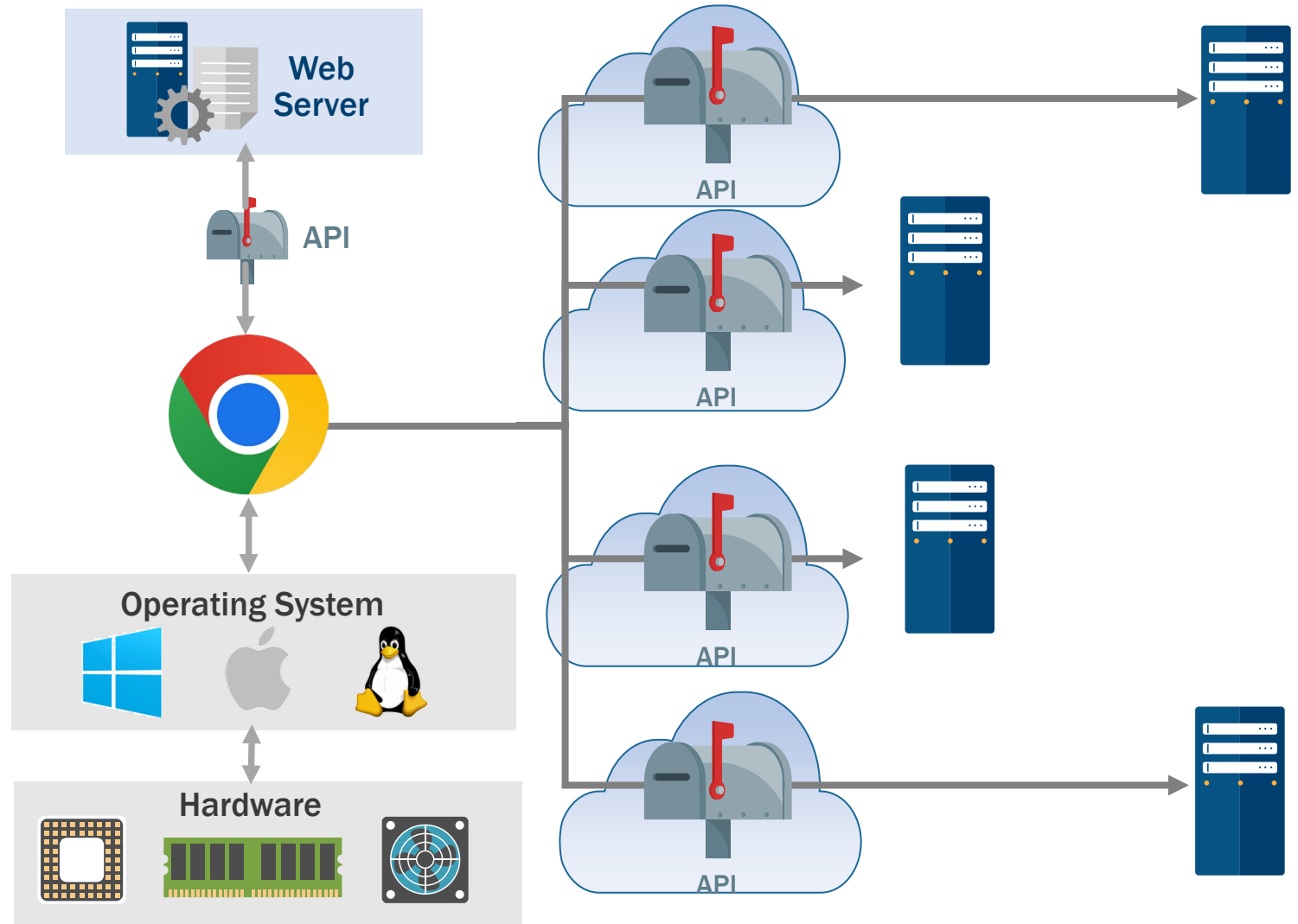
Chrome Doesn't Need to Know Backend Implementation



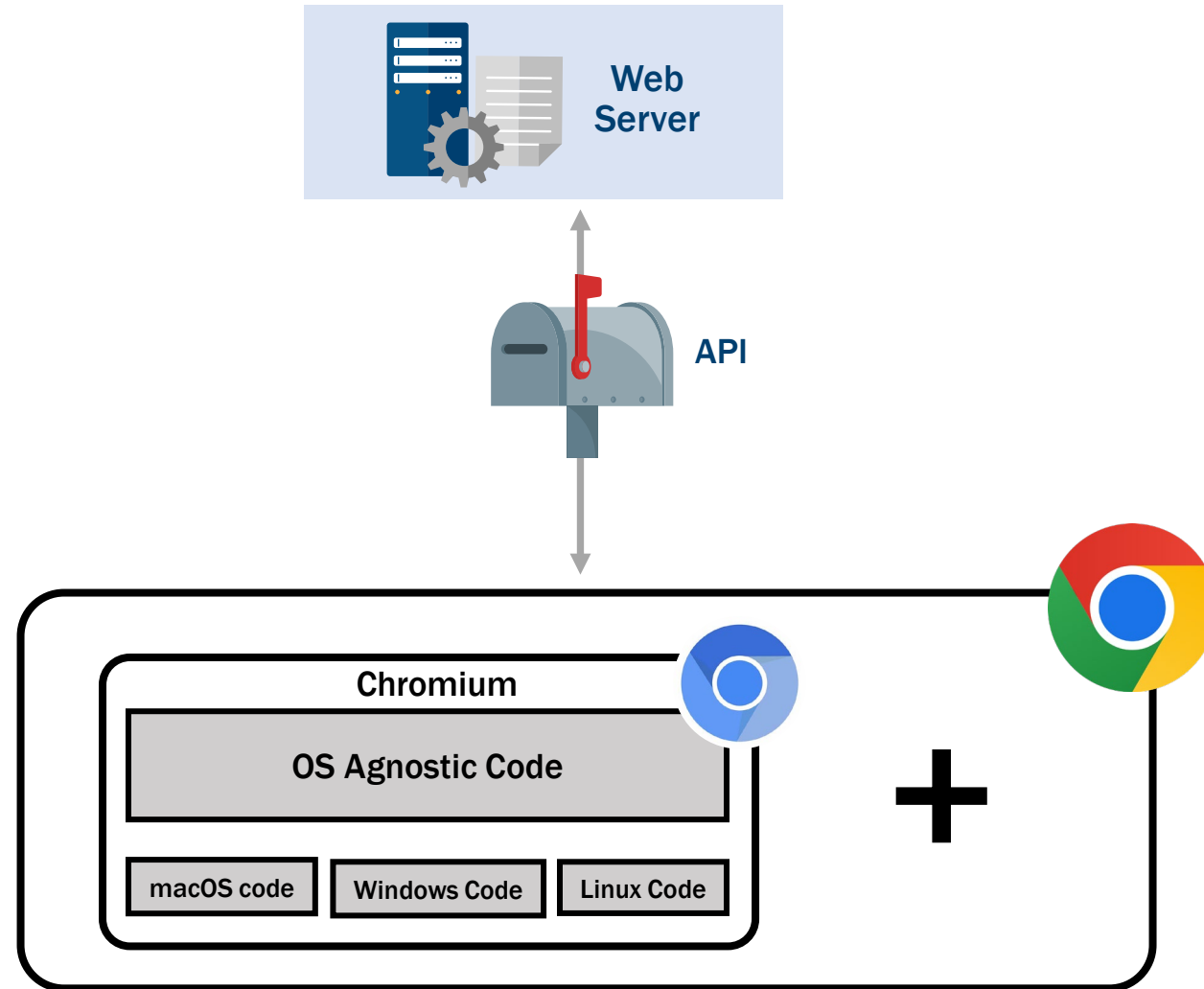
Chrome Communicates with Google Services Through Well-Defined Interfaces



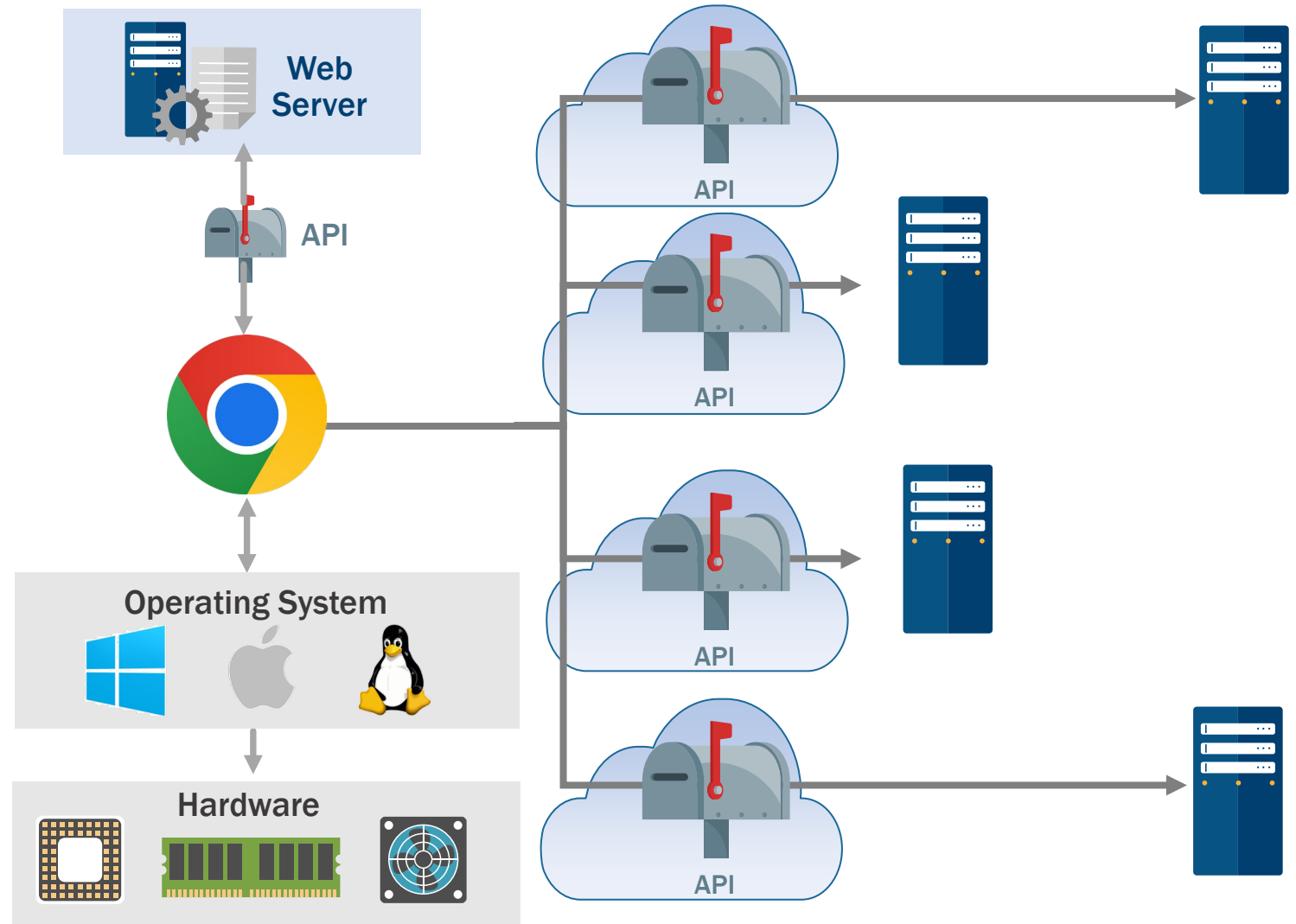
Divesting Chrome is Feasible



Divesting Chrome Would Not Impact Chrome's Ability to Retrieve and Render Web Pages



Divesting Chrome Is Feasible, Even If It May Change Chrome



The Buyer's Four Options for Each API

For each API, the new owner of Chrome can choose to:

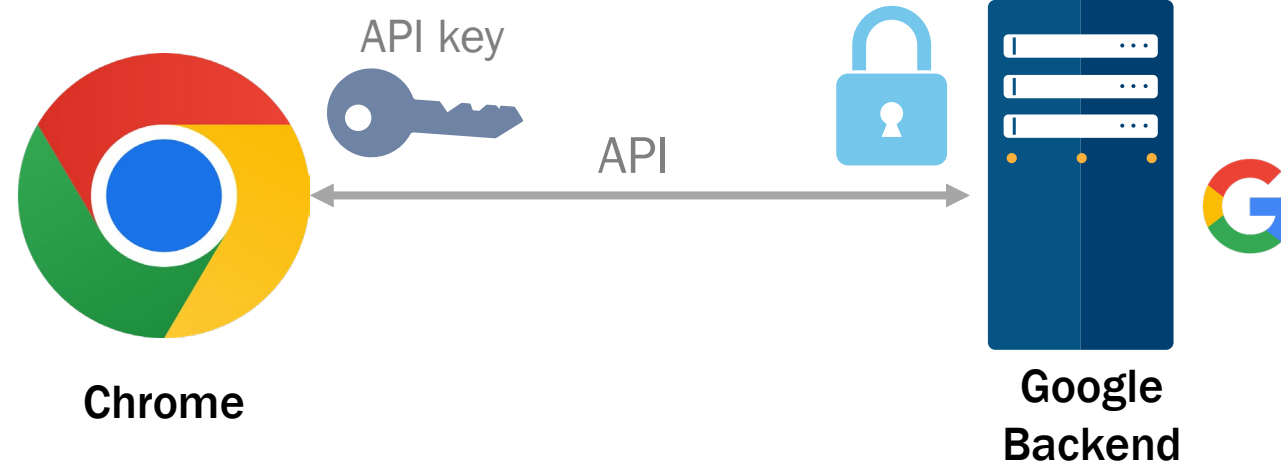
Leave unmodified the API call (e.g., purchase API keys)

Proxy the API call to a proxy server

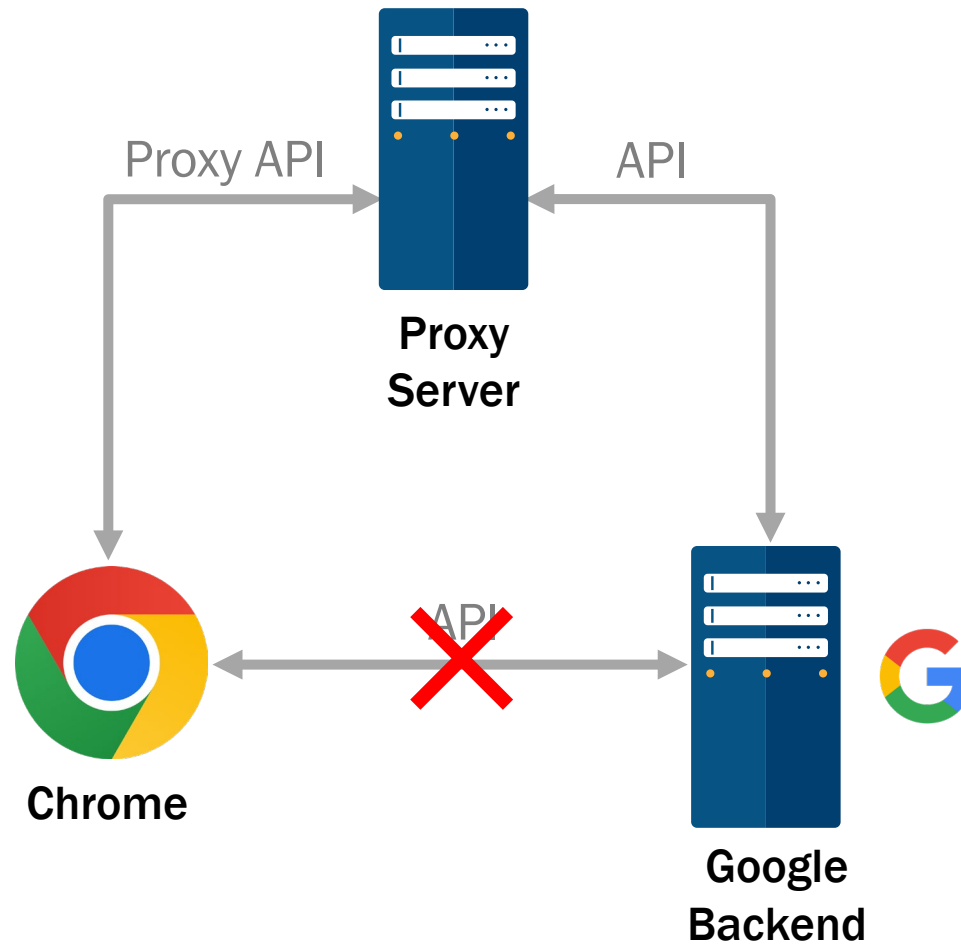
Substitute with an API call to a server run by third-party

Disable the API call

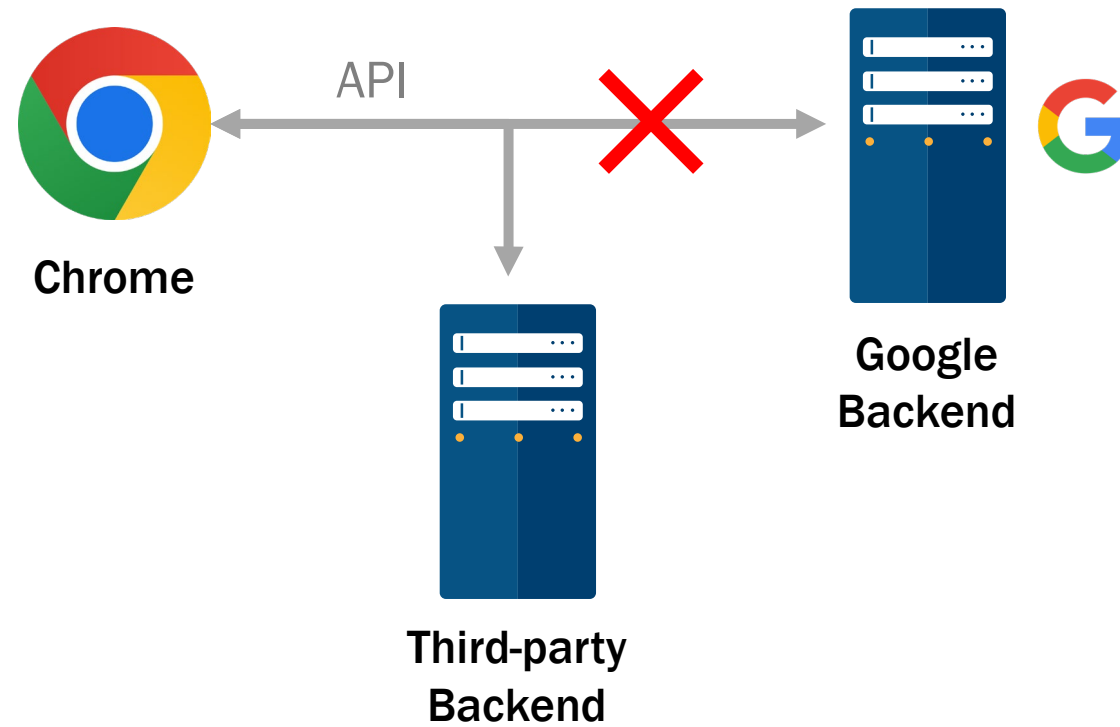
Leave Unmodified the API Call



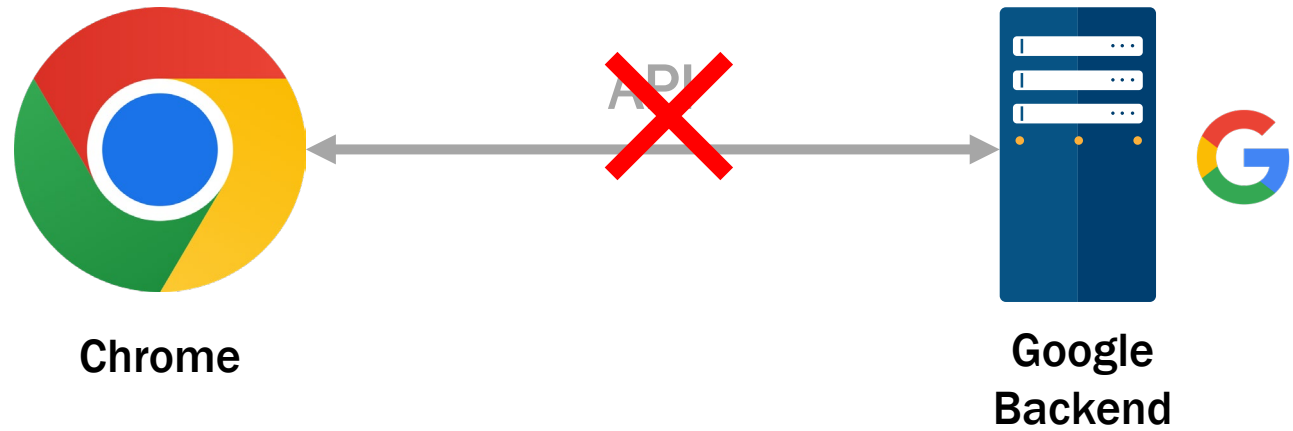
Proxy the API Call



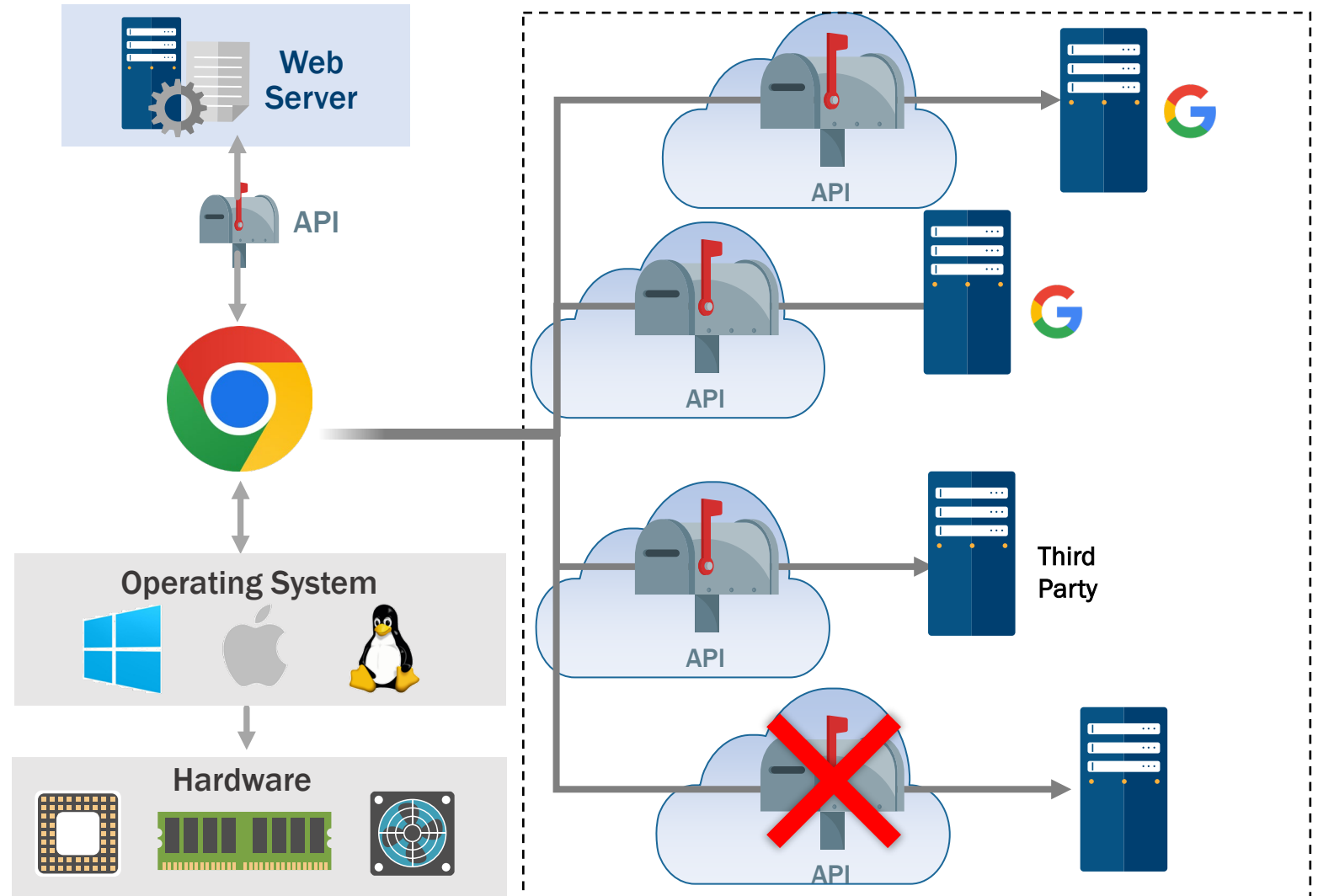
Substitute the API Call



Disable the API Call



Divesting Chrome Is Feasible, Even If It Likely Changes Chrome

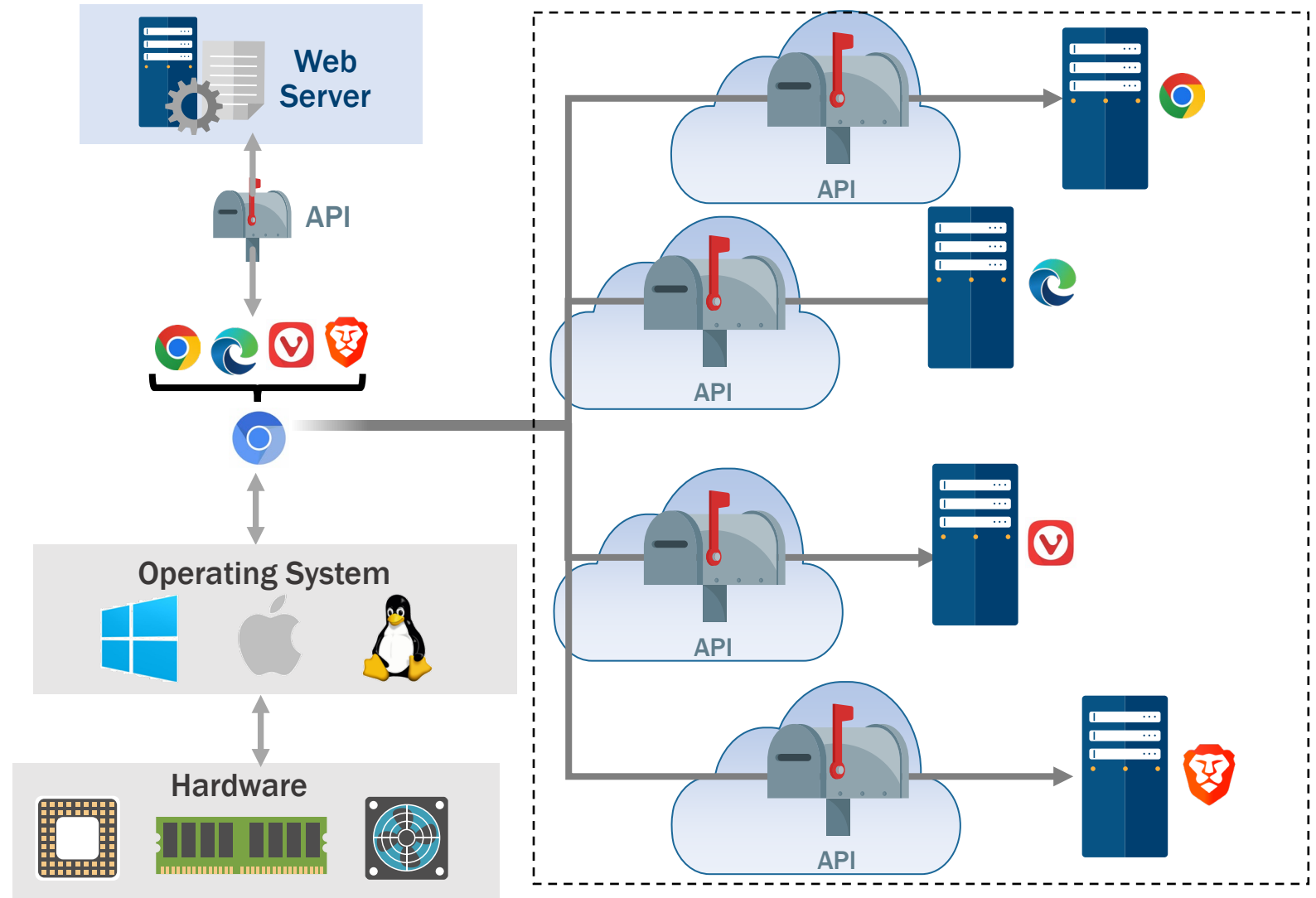


This Has All Happened Before

Services we replaced or turned off

Safe browsing	Speech input	Single sign-on (Gaia)	Developer Tools Remote
Nearby messages	Google Pay	Content Hash Fetcher	Debugging
Link Doctor	Drive API	Flighting Service	iOS Promotion Service
Ad blocking	Chrome OS hardware id	Component Updater Service	One Google Bar Download
User data sync	Device registration	RAPPORT service	Brand Code Configuration
Spellcheck	Google Maps Time zone	Chrome OS monitor	Fetcher
Suggest	Google Cloud Storage	calibration	WebRTC Logging
Translate	Cloud Print	Chrome OS device	Captive Portal Service
SmartLock	Google DNS	management	
Form Fill	Supervised Profiles	Android app password sync	
Push Notifications	Address Format	Offline Page Service	
WebStore	Network Location	Feedback	
Extension Store	Network Time	Domain Reliability Monitoring	
Maps Geolocation	Favicon service	Data Reduction Proxy	
Google Now	Google Cloud Messaging	Chrome Cleanup	

Microsoft



Post-Divestiture Chromium Will Receive Developer Attention



“Several leading organizations have already pledged their support for the initiative, including Google, Meta, Microsoft, and Opera. These organizations are committed to driving innovation in the Chromium ecosystem through their involvement in this initiative.”

“The Supporters of Chromium-Based Browsers follow an open governance model, drawing from best practices established by other successful Linux Foundation initiatives. It prioritizes transparency, inclusivity, and community-driven development.”

This Has All Happened Before



A tool for managing the deployment of distributed systems. Kubernetes is an offshoot of Google's closed-source Borg project.



A popular closed-source browser in the 1990s. Netscape created a non-profit organization called Mozilla, who then made the code open-source, rebranded it as Firefox.



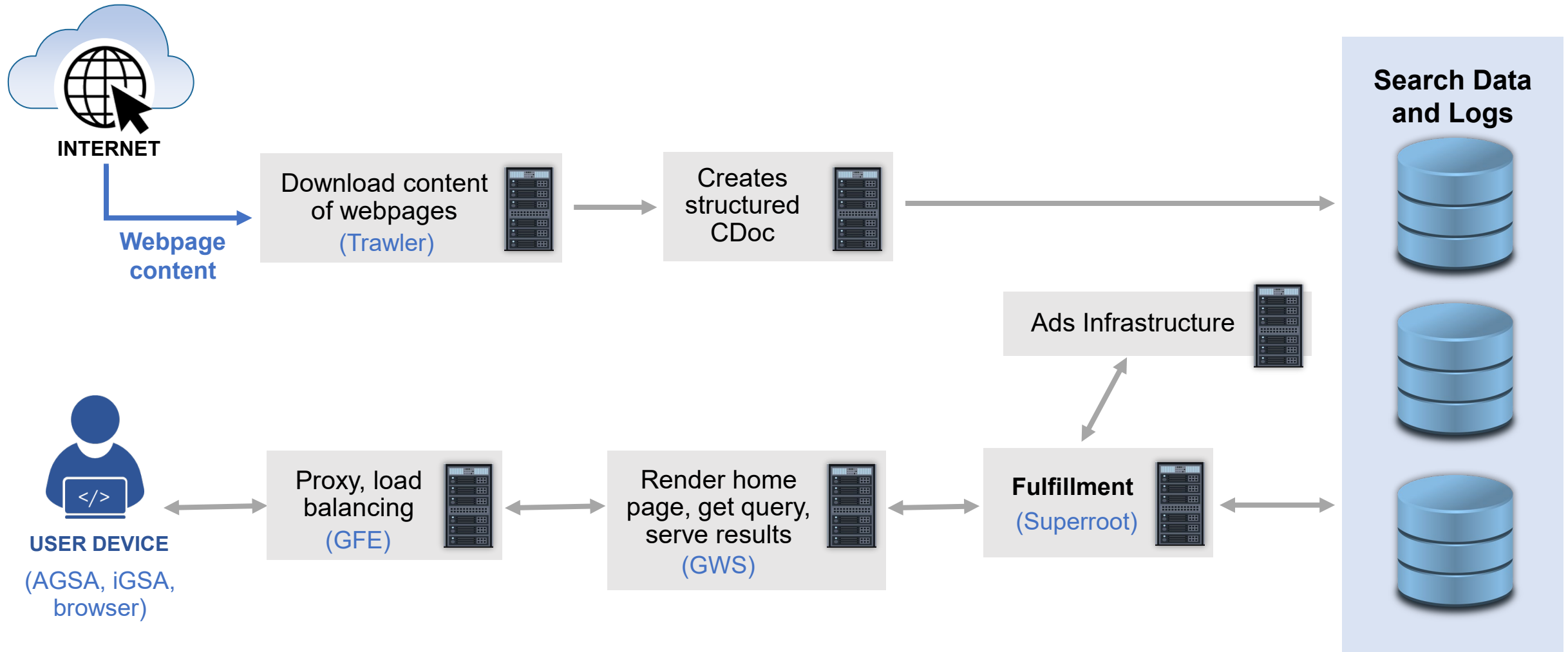
Blender was initially created as a closed-source program that was made open-source under the guidance of the non-profit Blender Foundation.

Opinion # 2: The Proposed Data Sharing and Syndication Remedies Are Feasible

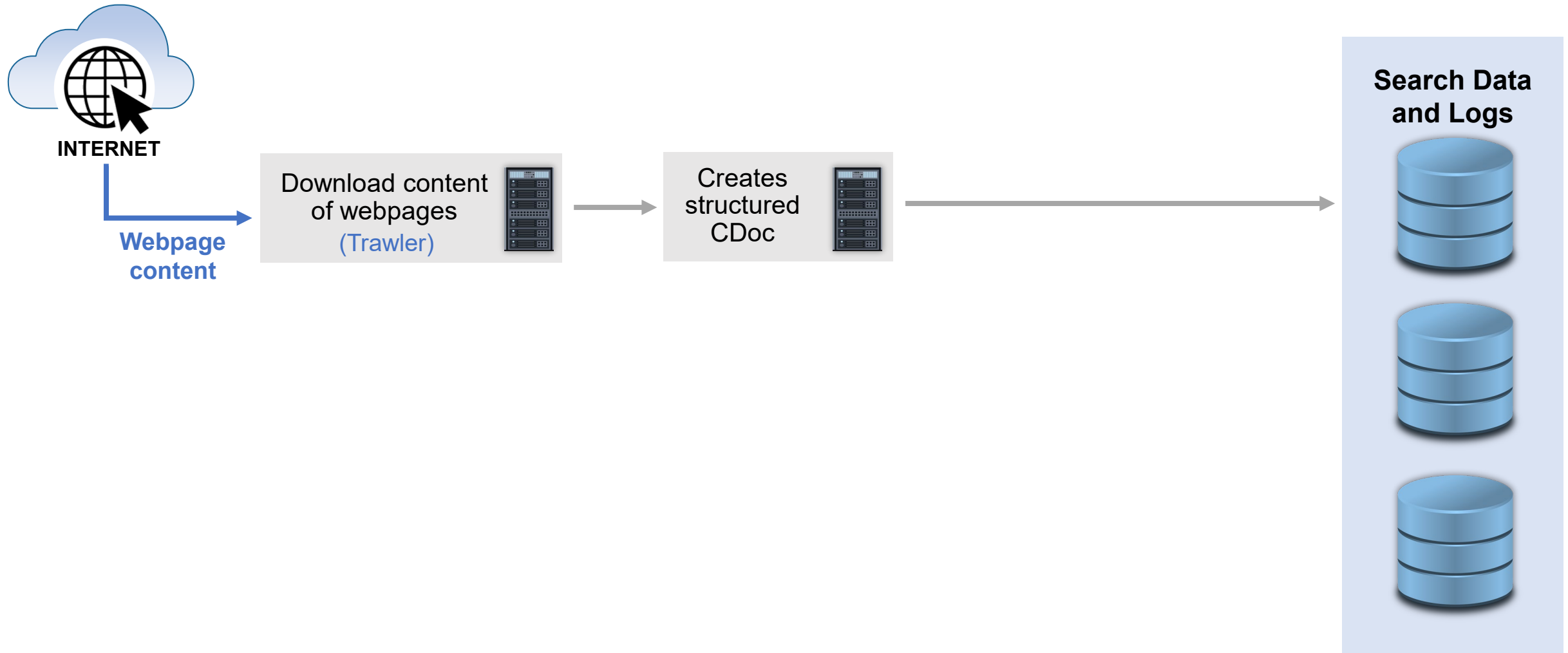
Data Sharing Remedies: Google's search infrastructure is amenable to providing search engine prerequisites and ads data to Qualified Competitors.

Syndication Remedies: Google can build upon its existing search syndication systems to provide a syndicated search feed, explanatory SERP data for each syndicated query, a synthetic search feed, and a syndicated ad feed.

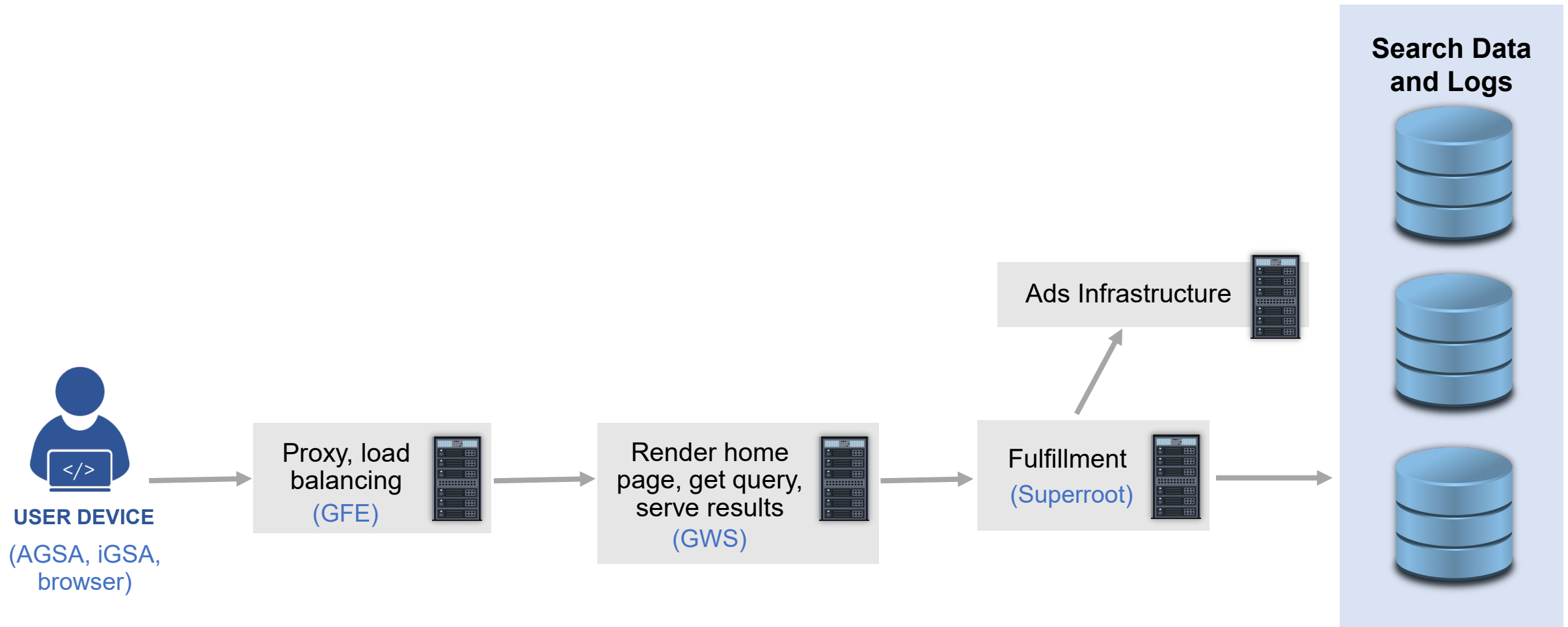
Overview of Google's Search Product



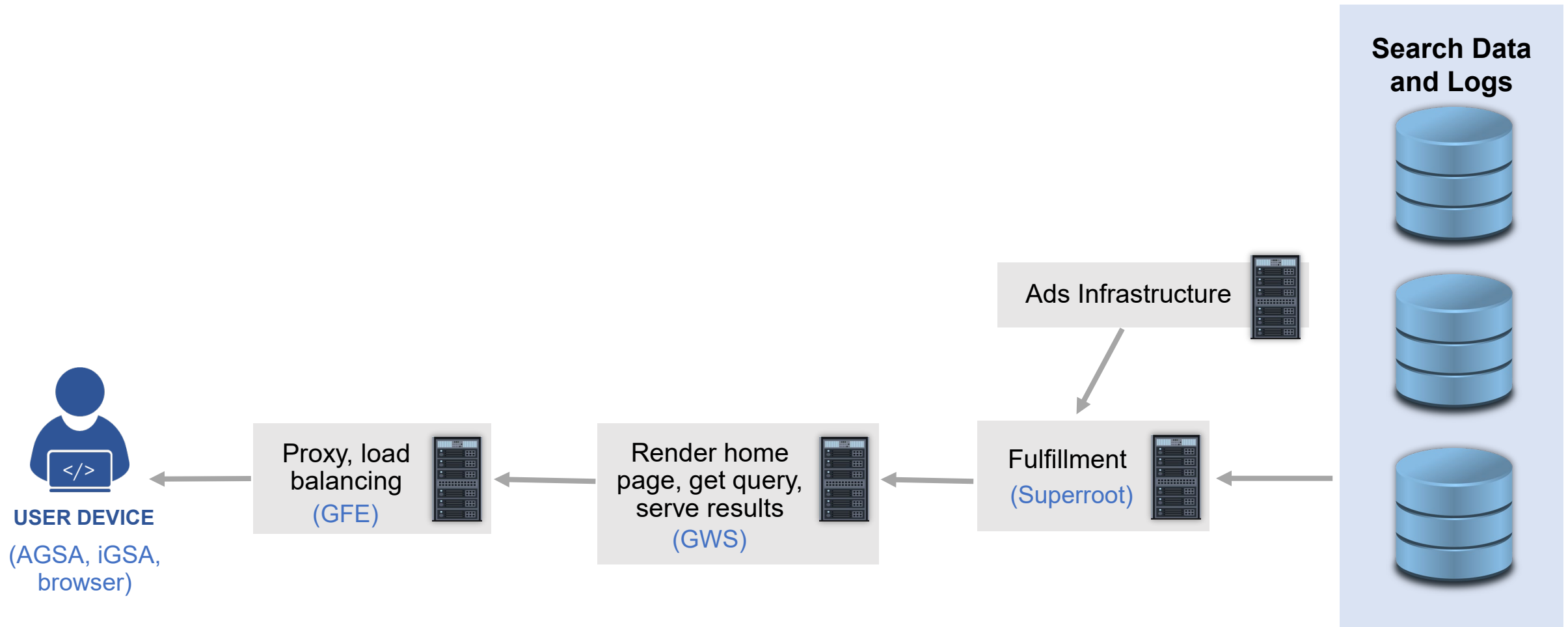
Indexing the Web



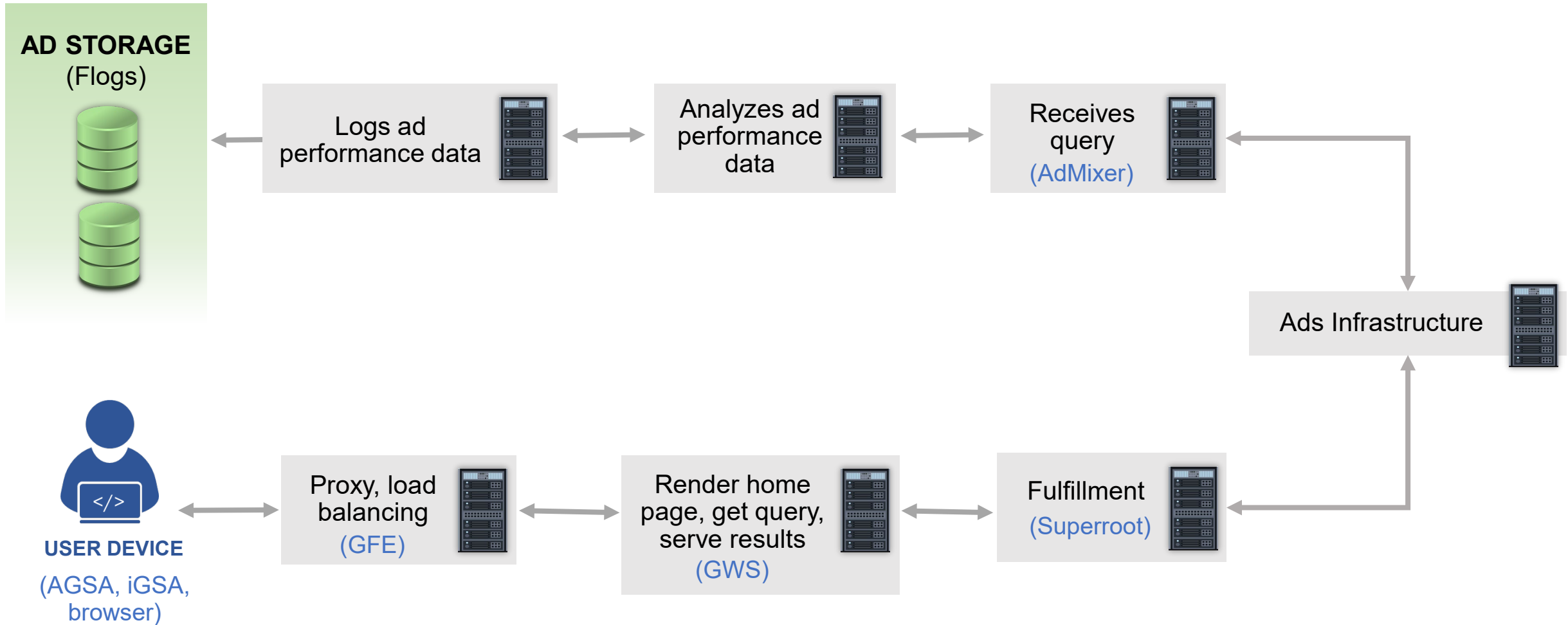
Part 1: Finding Results in Response to Queries



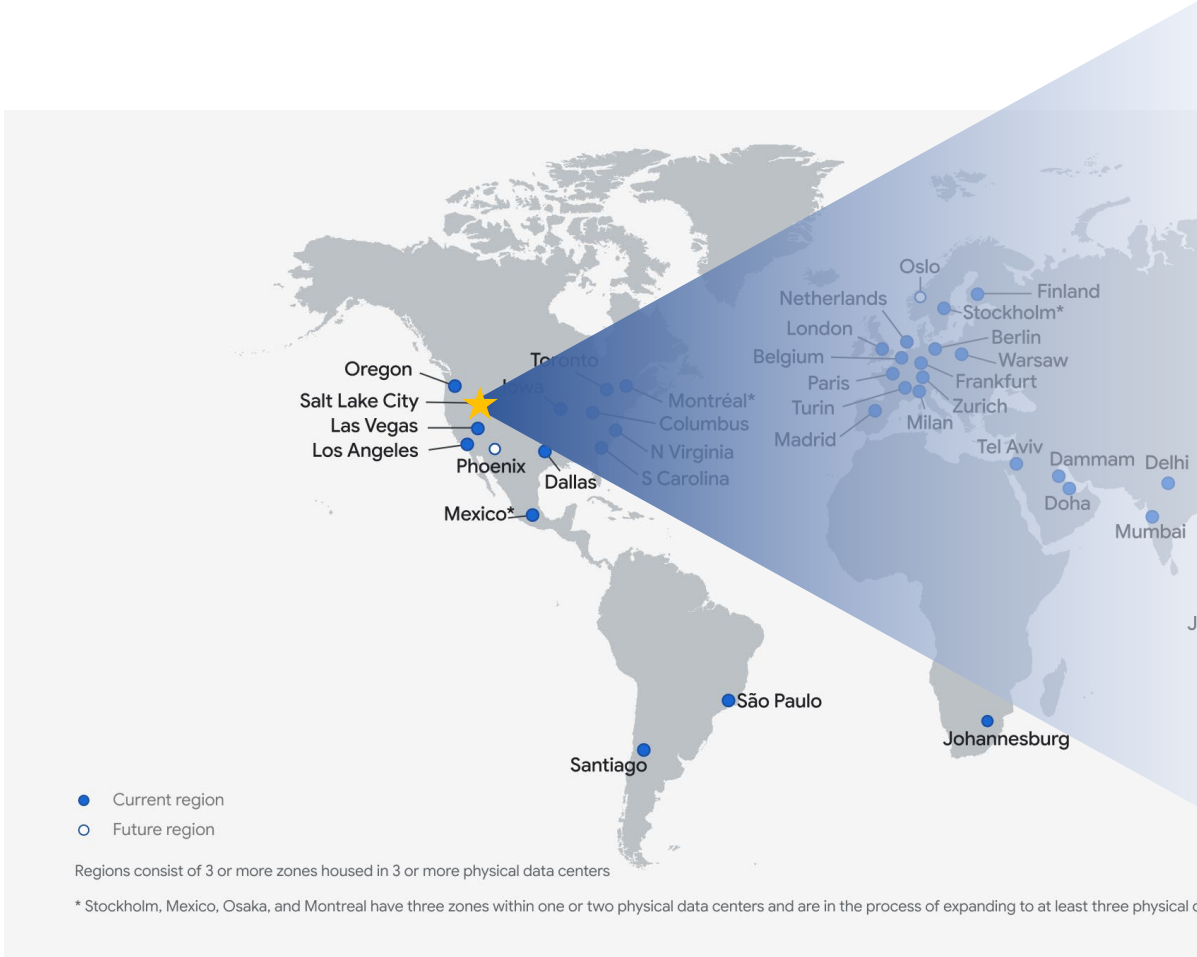
Part 2: Serving Search Results



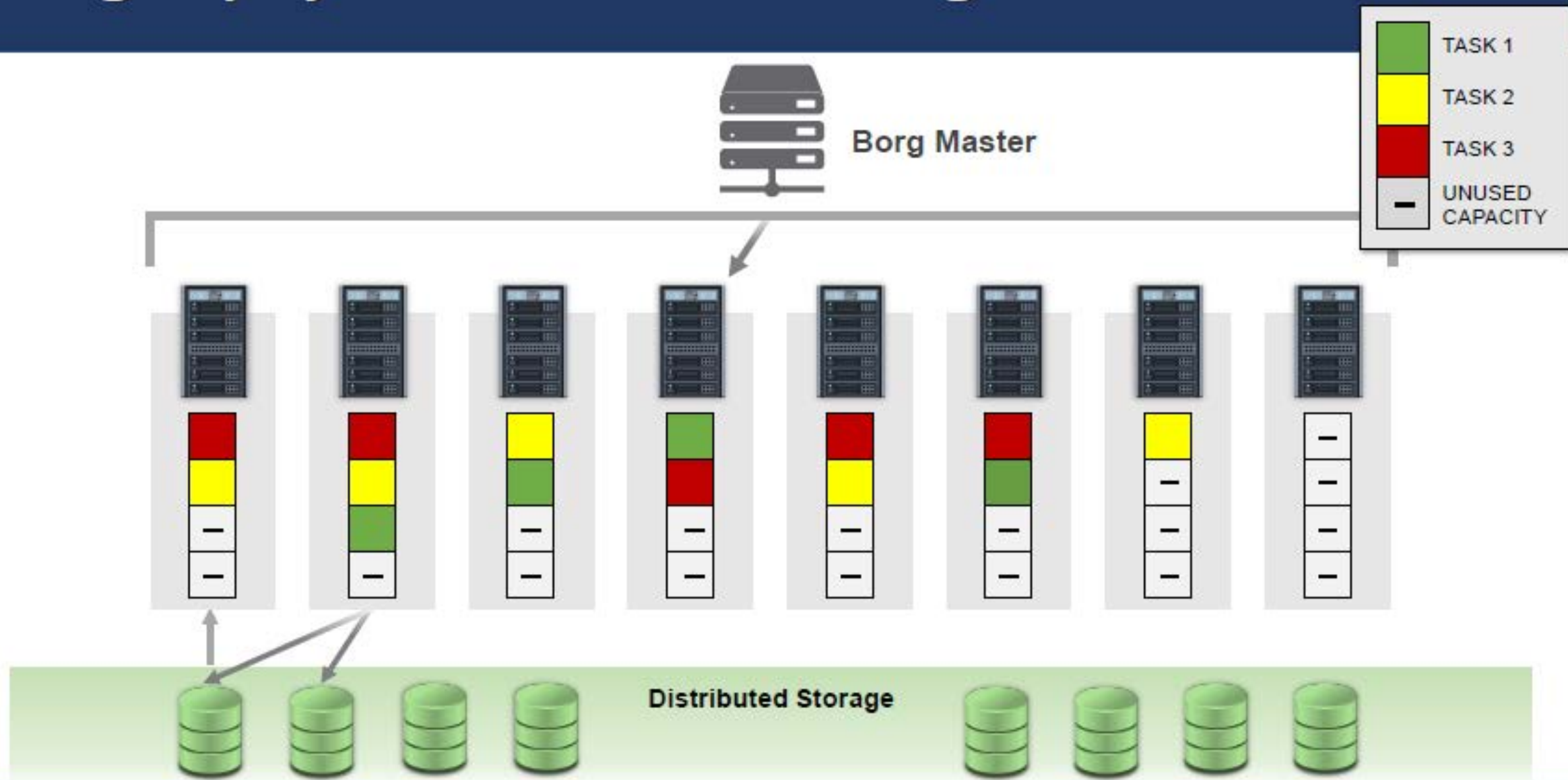
Selecting and Serving Ads



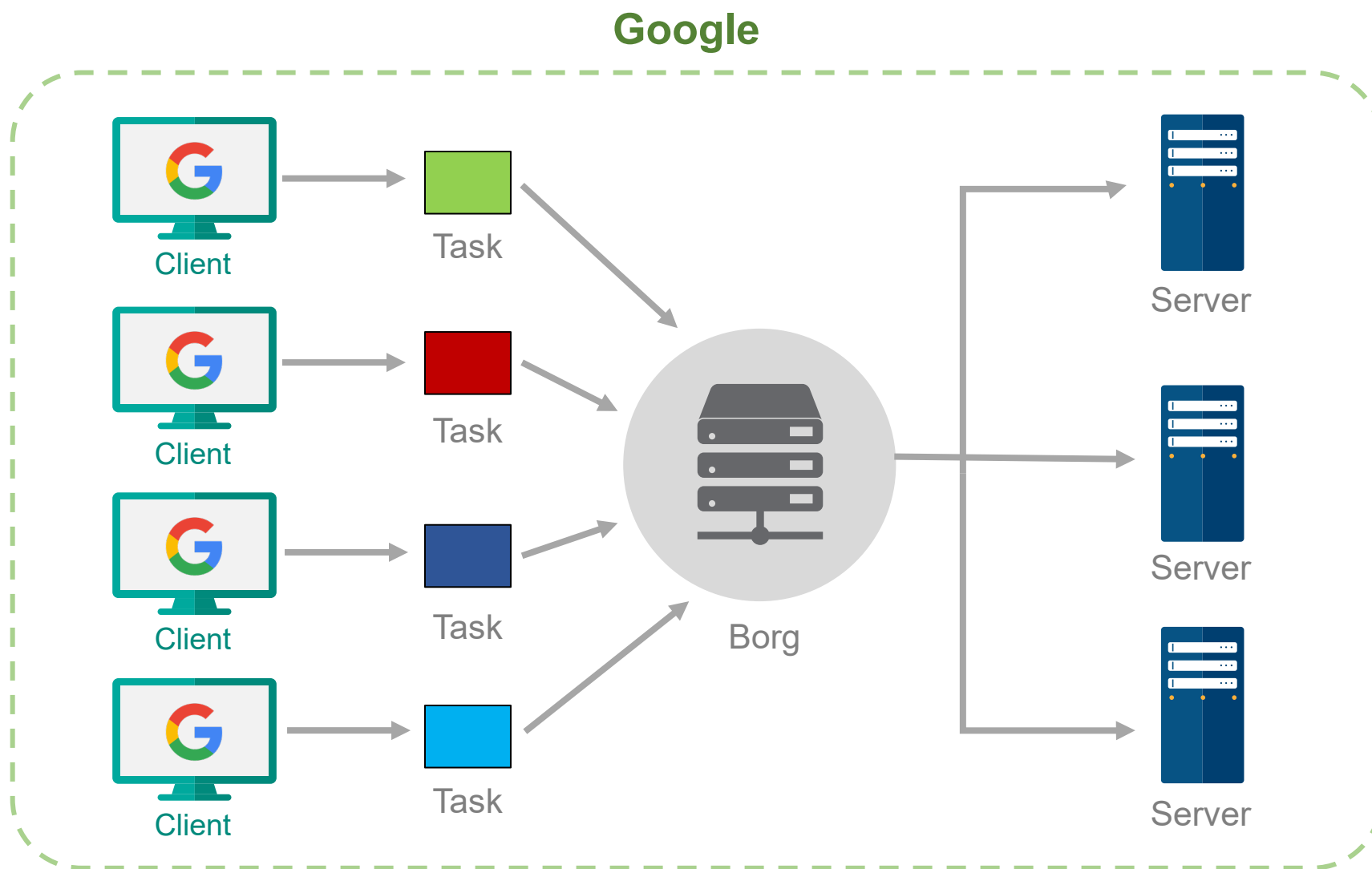
Hardware Infrastructure



Borg Deploys Software Across Google's Datacenters



Current Borg Example



Data Sharing Remedies

Case 1:20-cv-03010-APM Document 1184-1 Filed 03/07/25 Page 1 of 50

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF COLUMBIA

UNITED STATES OF AMERICA, <i>et al.</i> , Plaintiffs, v. GOOGLE LLC, Defendant.	Case No. 1:20-cv-03010-APM HON. AMIT P. MEHTA
STATE OF COLORADO, <i>et al.</i> , Plaintiffs, v. GOOGLE LLC, Defendant.	Case No. 1:20-cv-03715-APM HON. AMIT P. MEHTA

PLAINTIFFS' REVISED PROPOSED FINAL JUDGMENT

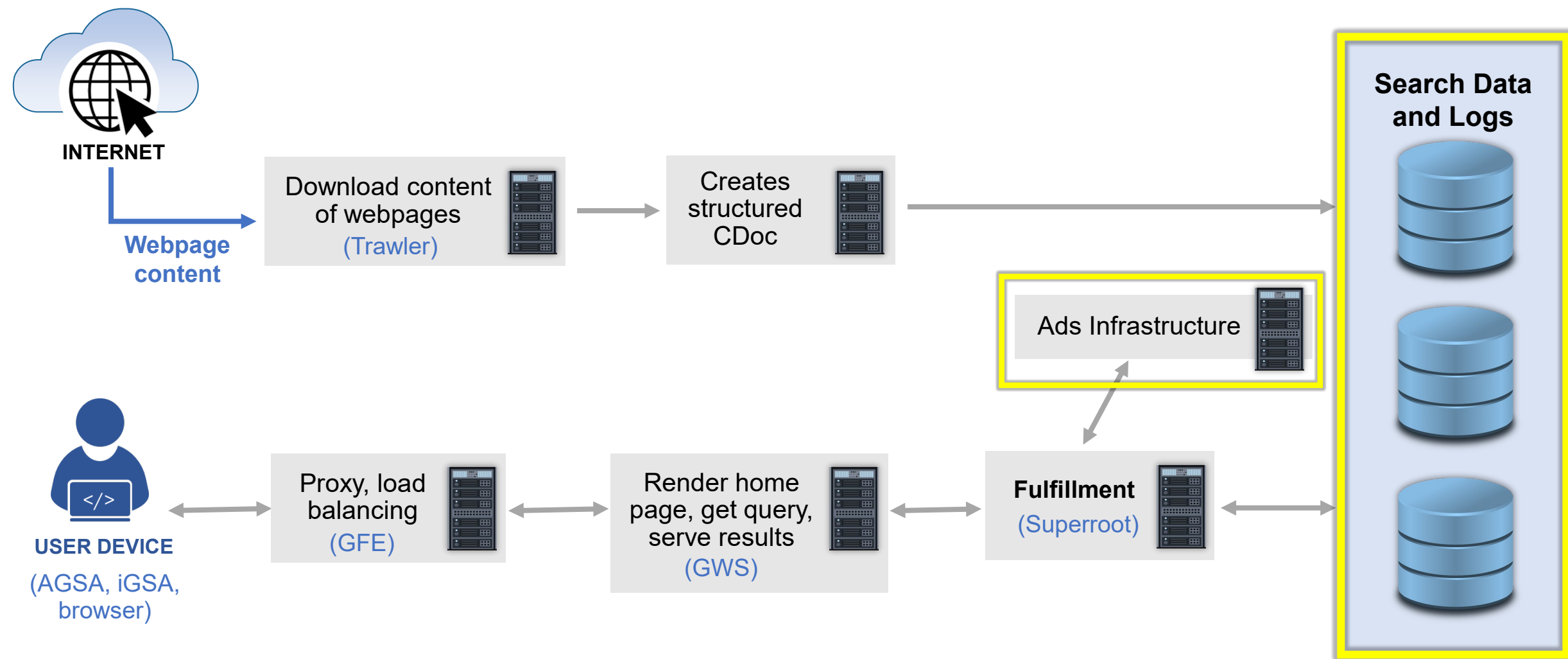
WHEREAS, Plaintiffs United States of America, and the States and Commonwealths of Arkansas, California, Georgia, Florida, Indiana, Kentucky, Louisiana, Michigan, Missouri, Mississippi, Montana, South Carolina, Texas, and Wisconsin, by and through their respective Attorneys General ("Co-Plaintiff States"), filed their Complaint on October 20, 2020, and their Amended Complaint on January 15, 2021;

AND WHEREAS, Plaintiffs Colorado, Nebraska, Arizona, Iowa, New York, North Carolina, Tennessee, Utah, Alaska, Connecticut, Delaware, District of Columbia, Guam, Hawaii, Idaho, Illinois, Kansas, Maine, Maryland, Massachusetts, Minnesota, Nevada, New Hampshire, New Jersey, New Mexico, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, Puerto Rico,

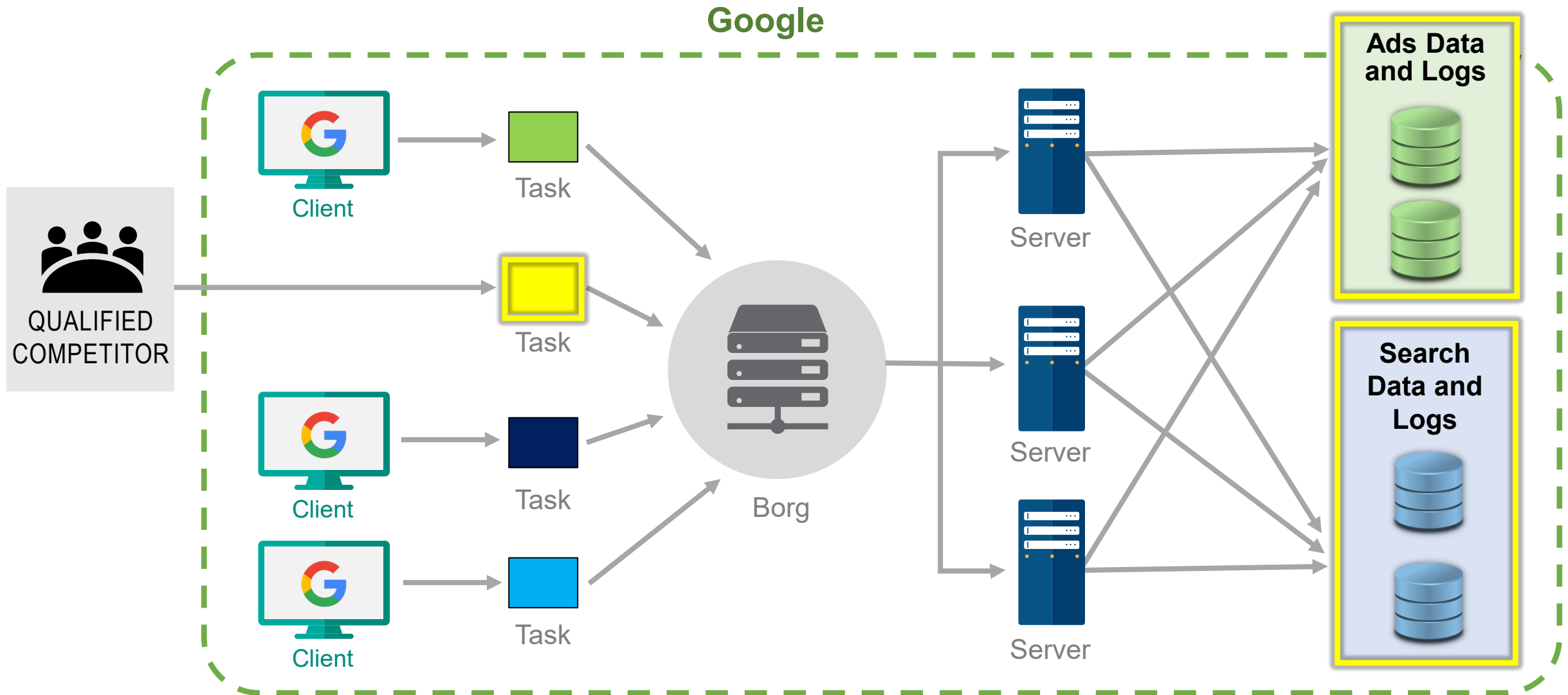
VI. REQUIRED DISCLOSURES OF SCALE-DEPENDENT DATA NECESSARY TO
COMPETE WITH GOOGLE

VIII. SEARCH TEXT AD TRANSPARENCY AND REDUCTION OF SWITCHING
COSTS

Data Sharing Remedies



Google's Existing Infrastructure Supports Data Sharing Remedies



Data Syndication Remedies

Case 1:20-cv-03010-APM Document 1184-1 Filed 03/07/25 Page 1 of 50

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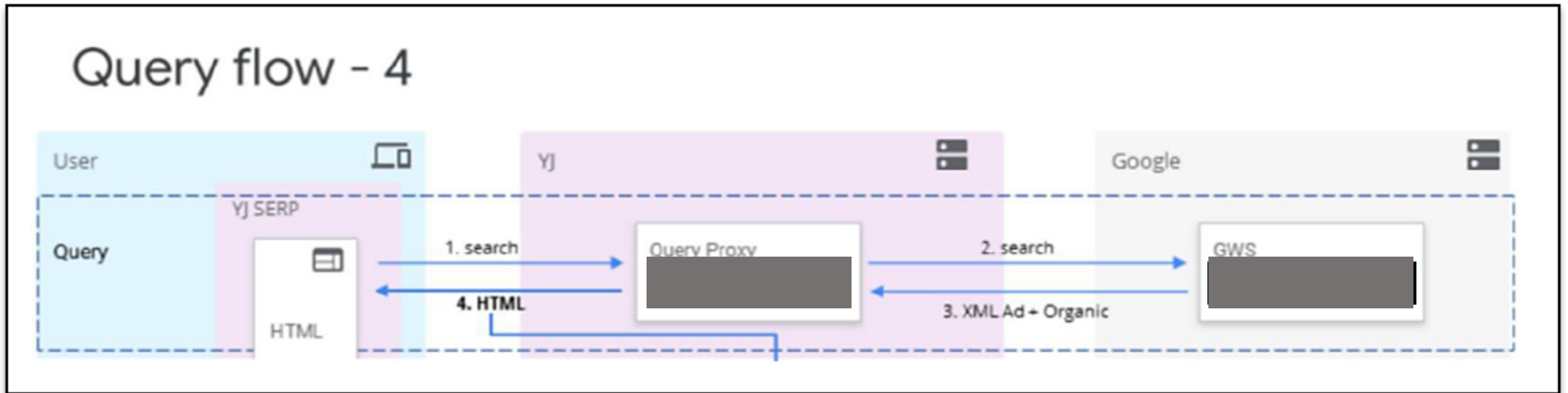
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VII. REQUIRED SYNDICATION OF SEARCH RESULTS NECESSARY TO BUILD GSE QUALITY AND SCALE OF QUALIFIED COMPETITORS

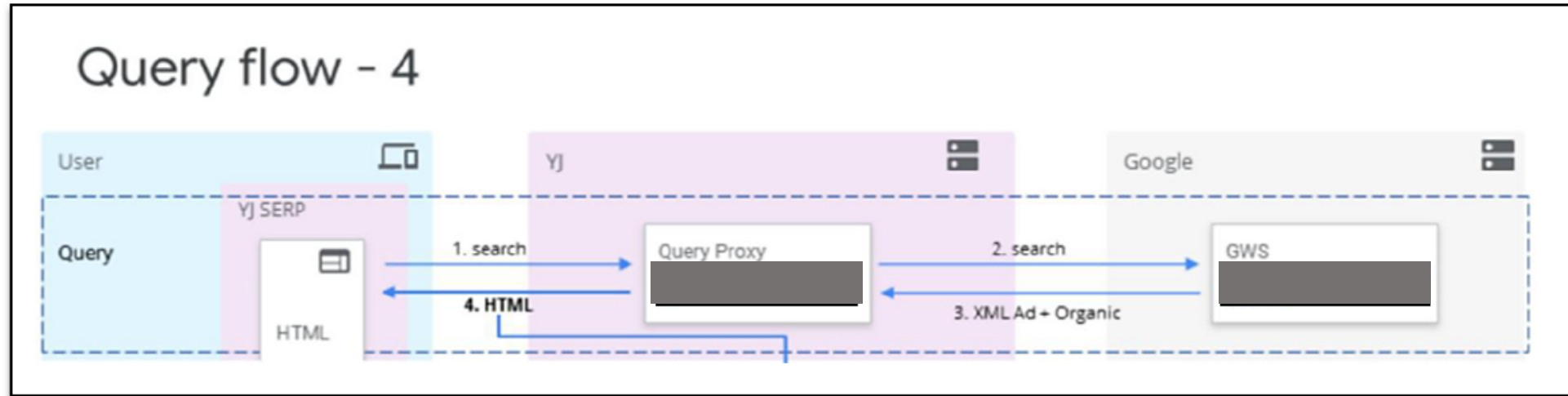
Source: Plaintiffs' RPFJ § VII

58

This Has All Happened Before



There Is Technical Precedent for Syndication



Professor Allan's Claims on Reverse-Engineering Are Misleading



CONTAINS HIGHLY CONFIDENTIAL INFORMATION

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CONTAINS HIGHLY
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EXPERT REPORT OF PROFESSOR JAMES ALLAN, PH.D.

March 14, 2025

18. Given the breadth of Plaintiffs' proposals and recent advances in LLMs, implementing Plaintiffs' proposals would allow a competitor to reverse engineer essentially all of Google's search results or, at a minimum, reverse engineer Google's current and future technologies (Section IX). In particular, I find that:

Professor Allan's Claims on Reverse-Engineering Are Misleading

1. QCs *do not want* to build a perfect replica of Google.
 - OpenAI and DuckDuckGo representatives have testified they *do not want* to replicate google.com.
2. A QC *could not* solely rely on syndicated feeds and logs to replicate a search engine.
 - **People:** engineers are needed to write code to replicate a service
 - **Time:** engineers must design, build, deploy, and test code
 - **Infrastructure:** code needs to run on physical datacenter infrastructure

Thus, QCs would be in a perpetual game of catch-up.

Professor Allan's Deposition Testimony

Q. So you're not offering an opinion on quality infrastructure latency that it would take a qualified competitor using this type of LLM or actually any -- any of the reverse engineering methodologies in your report?



A. Right. All of what I'm focusing on is what is disclosed, whether directly or reverse engineering or mimicking, and what a competitor -- you know, and that these are -- these are complicated technologies that are being disclosed.

And I'm not saying -- I'm saying the competitor could use that to improve their system. I'm not saying whether their system would then be fast, and I have not investigated how fast. Because there's too many variables in that. It's too much of a I don't know what hardware they might have. I don't know what sort of engineering expertise they have inhouse. It's just -- there are too many variables there to offer that opinion.

Prohibition on Self-Preferencing in the RPFJ

Case 1:20-cv-03010-APM Document 1184-1 Filed 03/07/25 Page 1 of 50

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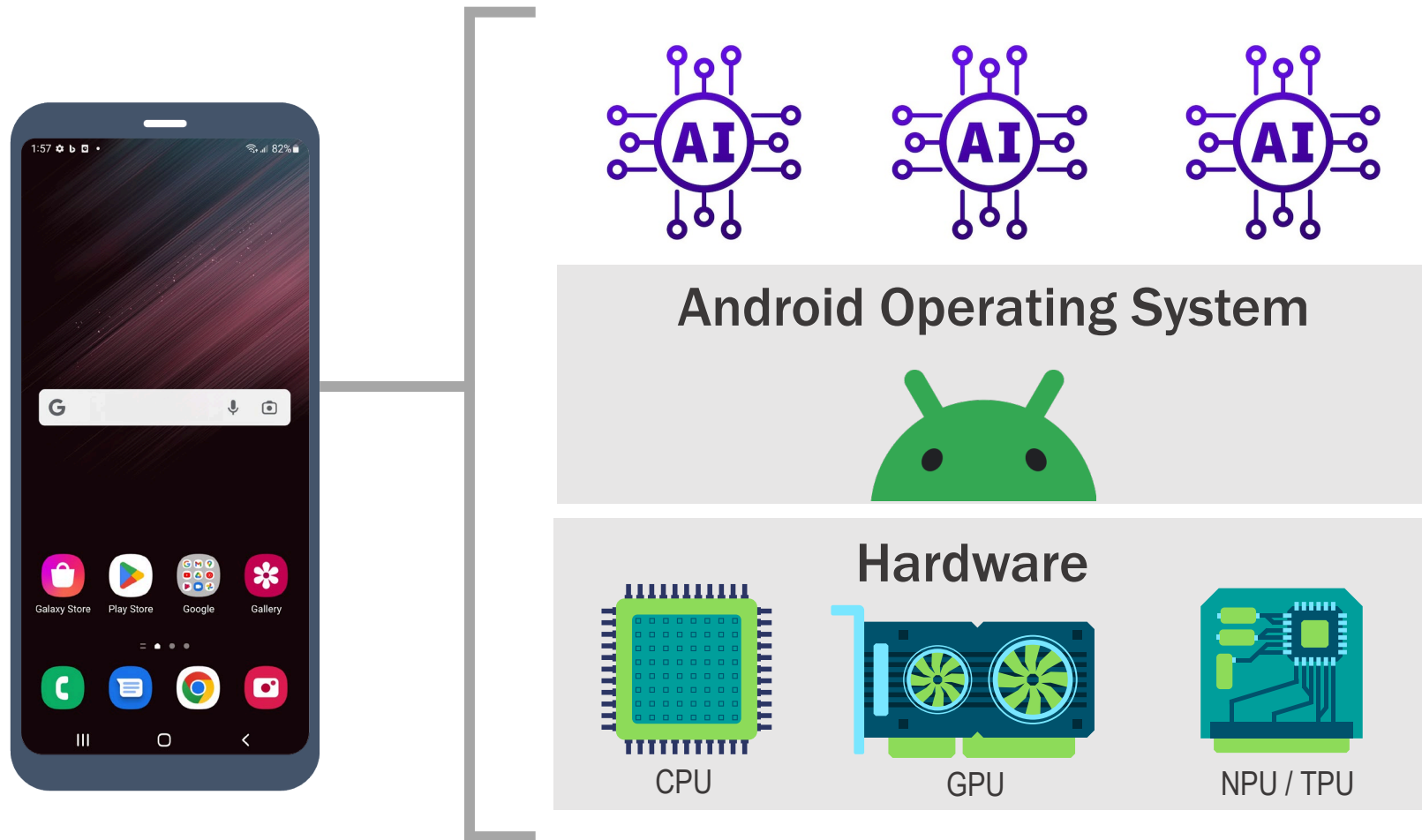
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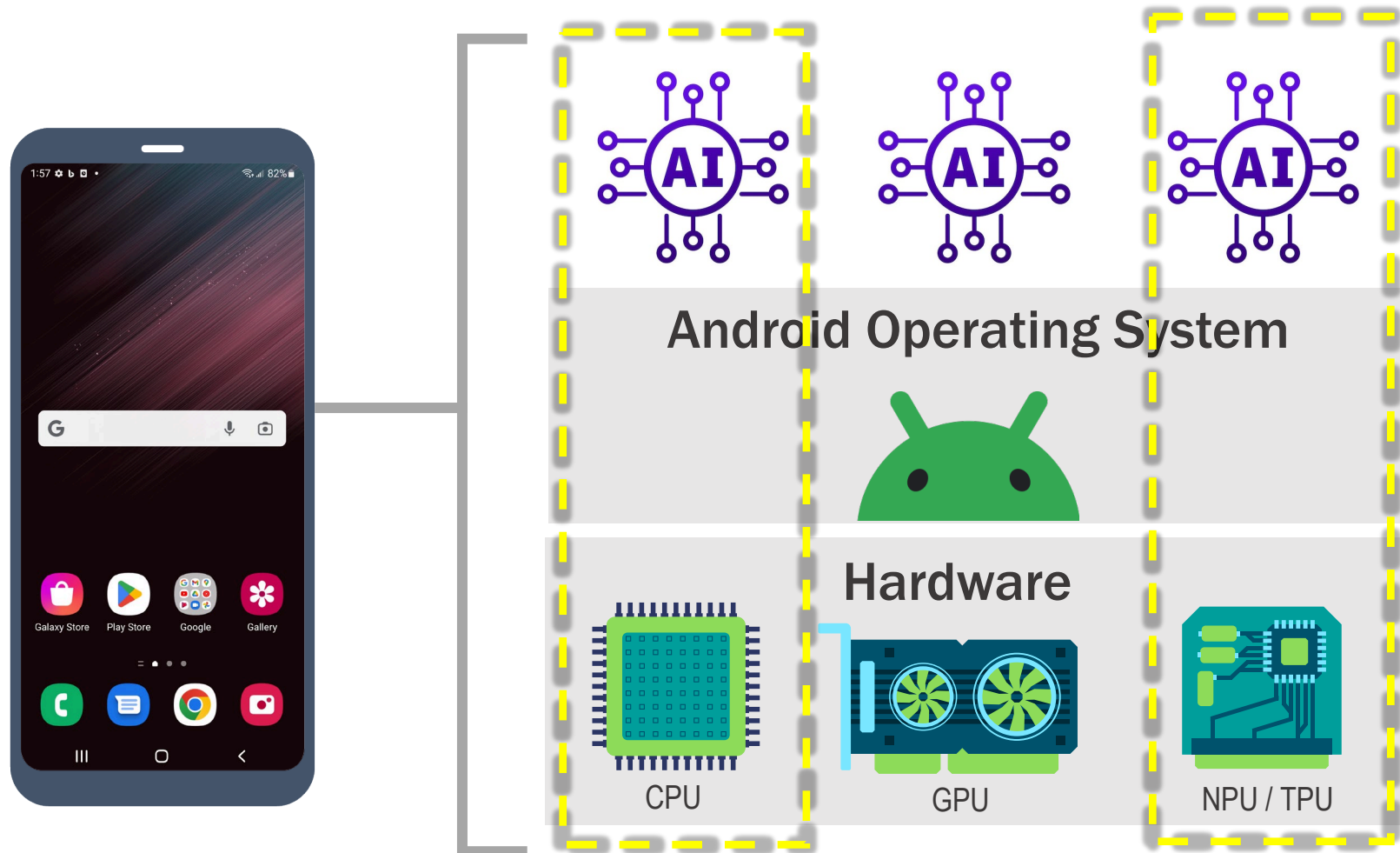
B. Self-Preferencing Prohibited: Google must not use its ownership and control of Android, or any other Google product or service, to:

1. make any GSE, Search Access Point, GenAI Product, or On-Device AI explicitly or implicitly mandatory on Android Devices, for example, by preventing interoperability between Android AICore or a Google Grounding API and Competitor products and services in the GSE or Search Text Ads markets;

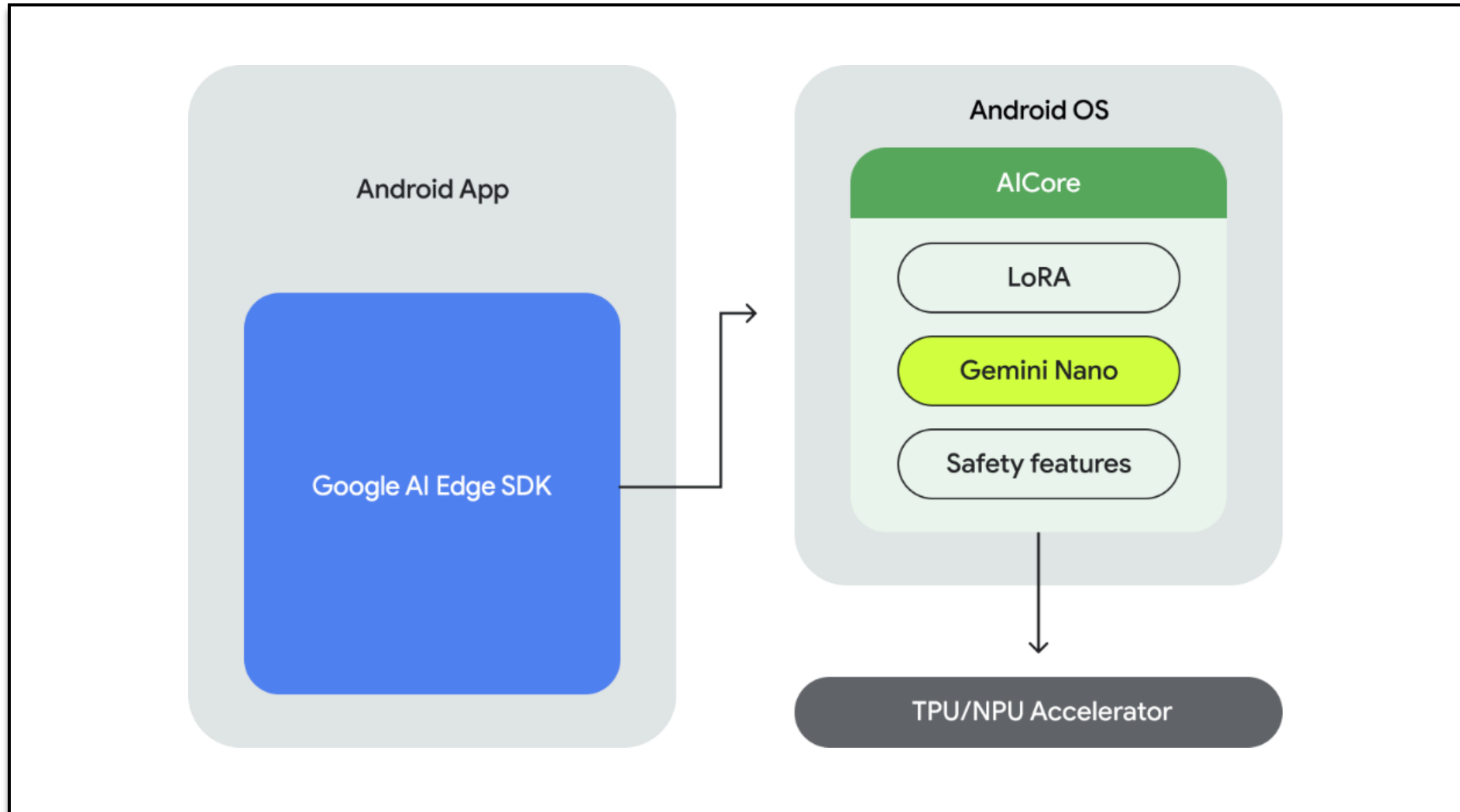
Multiple AI Models Can Run on an Android Phone



AI Models Run More Efficiently If They Run on Specialized Hardware



What Is AICore?

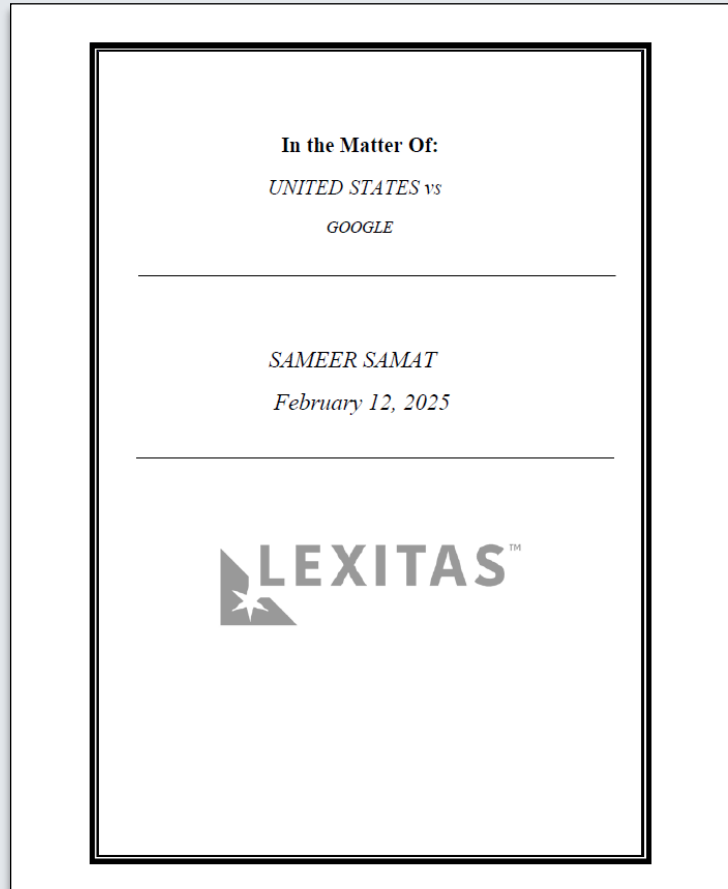


Google Is Aware of the Advantages AICore Can Give AI Models

Google unambiguously states in public-facing technical documentation that running models on AI accelerators via AICore is faster than running models outside of AICore on a phone's CPUs and GPUs.

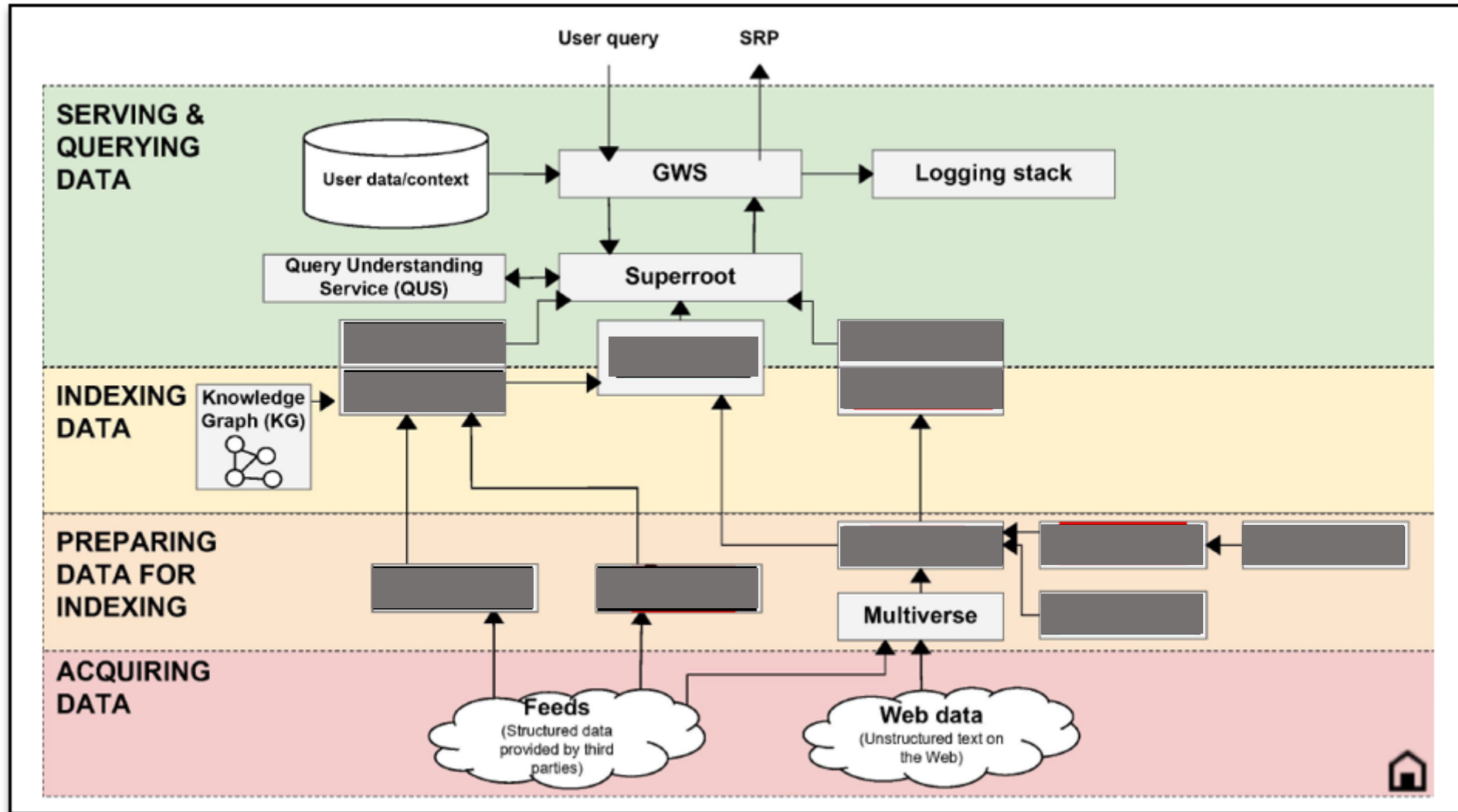
“AICore is the new system-level capability introduced in Android 14 to provide Gemini-powered solutions for high-end devices, including integrations with the latest ML accelerators, use-case optimized LoRA adapters, and safety filters.”

Android's Lead Executive Confirms AICore's Exclusivity



- Q. But sitting here today, are you aware of any ways for a developer to access a device resident version of Gemini Nano other than through AICore?
- A. I'm not. But I'm also not following all the ways that they are – they may be doing that, and there could – they could exist.
- * * *
- Q. Can AICore host other device-resident LLM models?
- A. Today it cannot. We simply haven't gotten to that part of our road map yet.

Combined Search Infrastructure



Unregulated AI Models Pose Security Risk

GUILLOTINE: Hypervisors for Isolating Malicious AIs

James Mickens
mickens@g.harvard.edu
Harvard University

Sarah Radway
sradway@g.harvard.edu
Harvard University

Ravi Netravali
rnetravali@cs.princeton.edu
Princeton University

ACM Reference Format:
James Mickens, Sarah Radway, and Ravi Netravali. 2025. Guillotine: Hypervisors for Isolating Malicious AIs. In *Workshop on Hot Topics in Operating Systems (HOTOS '25)*, May 14–16, 2025, Banff, AB, Canada. ACM, New York, NY, USA, 9 pages. <https://doi.org/10.1145/3713082.3730391>

Abstract
As AI models become more embedded in critical sectors like finance, healthcare, and the military, their inscrutable behavior poses ever-greater risks to society. To mitigate this risk, we propose Guillotine, a hypervisor architecture for sandboxing powerful AI models—models that, by accident or malice, can generate existential threats to humanity. Although Guillotine borrows some well-known virtualization techniques, Guillotine must also introduce fundamentally new isolation mechanisms to handle the unique threat model posed by existential-risk AIs. For example, a rogue AI may try to introspect upon hypervisor software or the underlying hardware substrate to enable later subversion of that control plane; thus, a Guillotine hypervisor requires careful co-design of the hypervisor software and the CPUs, RAM, NIC, and storage devices that support the hypervisor software, to thwart side channel leakage and more generally eliminate mechanisms for AI to exploit reflection-based vulnerabilities. Beyond such isolation at the software, network, and microarchitectural layers, a Guillotine hypervisor must also provide physical fail-safes more commonly associated with nuclear power plants, avionic platforms, and other types of mission-critical systems. Physical fail-safes, e.g., involving electromechanical disconnection of network cables, or the flooding of a datacenter which holds a rogue AI, provide defense in depth if software, network, and microarchitectural isolation is compromised and a rogue AI must be temporarily shut down or permanently destroyed.

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HOTOS '25, May 14–16, 2025, Banff, AB, Canada
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ACM ISBN 978-8-4007-1475-7/2025/05
<https://doi.org/10.1145/3713082.3730391>

1 MOTIVATION

A machine learning model tries to emulate human reasoning. To do so, a model encodes observations about training data using numerical parameters and links between those parameters. Current state-of-the-art models are so large that their internal organization is opaque to their human creators. For example, the open-source BLOOM model has 176 billion parameters [27], the open-source Llama 3.1 model has 405 billion parameters [38], and the closed-source GPT-4 model is rumored to have more than a trillion parameters [59]. Humans cannot directly understand the relationships between such vast constellations of parameters. Automated methods for understanding those relationships (and how they generate model outputs) are an active area of research. Unfortunately, such model interpretability techniques appear to be inherently fragile. Consider the task of explaining LLM inferences. The soundness of LLM interpretability techniques is vulnerable to instabilities in the underlying LLM itself [60]. For example, the fact that LLMs are sensitive to minor changes in prompt phrasing [56] can result in a model's self-reported chain-of-thought being an unfaithful representation of the model's actual reasoning process [68]. Furthermore, an LLM's tendency to hallucinate [64] can manifest itself not only in the model's answer to a question, but in the model's explanation for that answer [80]. The opacity of model reasoning is troubling because models are increasingly connected to societally important infrastructure. For example, in financial settings, misbehaving models can generate huge monetary losses due to bugs. Those bugs might have been unintentionally introduced by model makers [41] or intentionally induced by adversarial examples [78]. In warfighting scenarios, military leaders are already concerned that AI-governed weapons may escalate conflicts due to ignorance of geopolitical nuance [42]; these escalation problems are exacerbated when AI makes decisions too quickly for humans to review those decisions [33]. Model alignment techniques [77] try to ensure that models adhere to human-defined behavioral norms. However (and concerning), models can fake alignment compliance during training to later act in non-aligned ways post-deployment [21]. Researchers have also demonstrated that, in the specific context of LLMs, if model alignment does not completely eliminate the possibility of an undesirable model behavior, an adversarial prompt can always elicit that behavior [77]. Thus, society faces an increasing risk that an artificial general intelligence (AGI) model which matches or exceeds human reasoning will generate catastrophic harms in real life.

Abstract

As AI models become more embedded in critical sectors like finance, healthcare, and the military, their inscrutable behavior poses ever-greater risks to society. To mitigate this risk, we propose Guillotine, a hypervisor architecture for sandboxing powerful AI models—models that, by accident or malice, can generate existential threats to humanity. Al-

ChromeOS and Aluminium Architecture

Tech Stack

Aluminium ("ChromeOS" built on the Android stack) will leverage Android's pre-existing stack.

Initial high-level [gaps and dependency analysis](#).

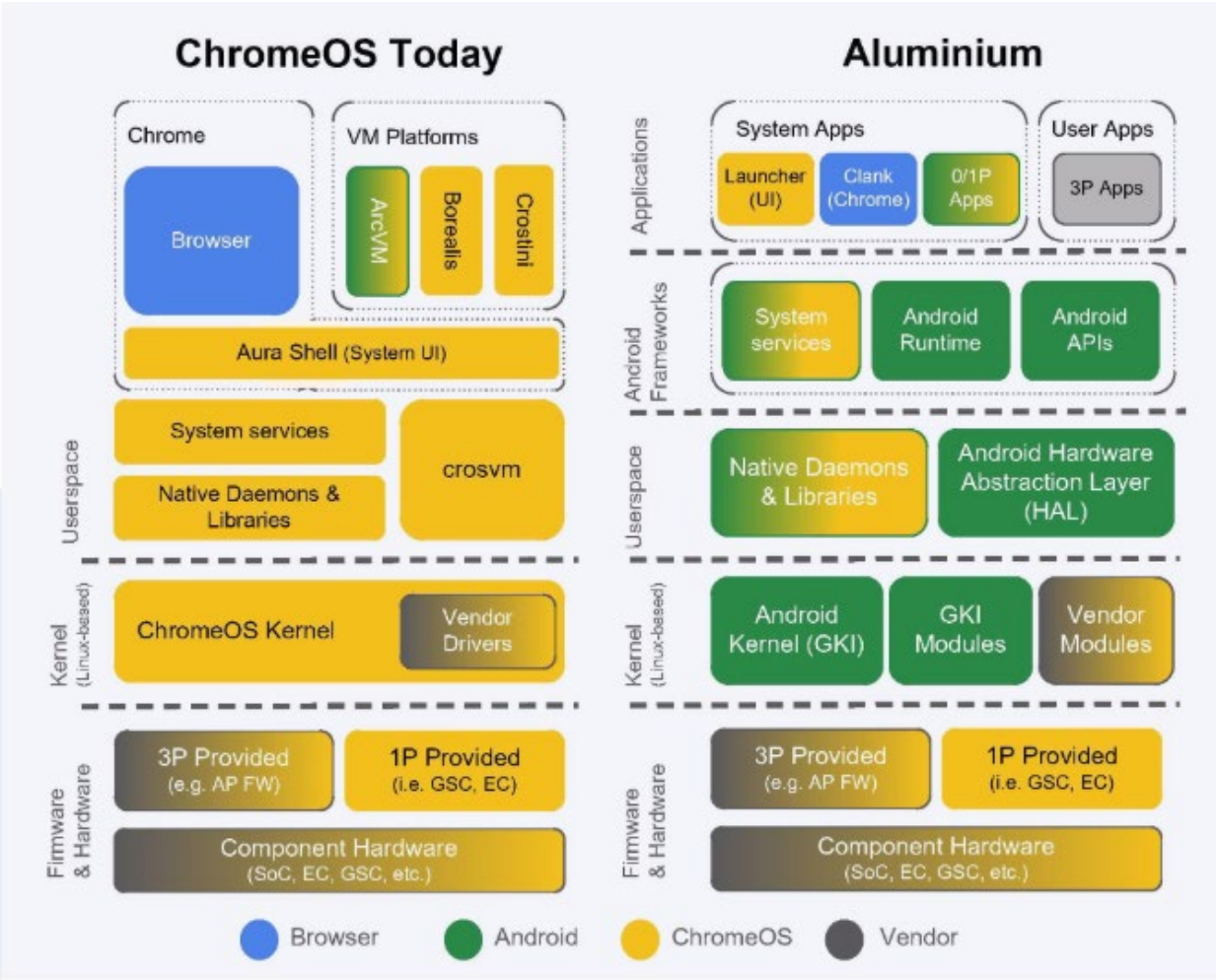
Through targeted ownership of key components AL would retain:

10 years of Google-provided updates

Security integrity from the hardware through the OS

Desktop look and feel

ChromeOS mgmt layer



Search Ads Machine Learning Infrastructure

[AdsML Efficiency, Convergence, and Privacy]

Authors: carlson, sunitav
Last Update: October 12, 2020

See also: [Trix](#)

Description

[AdsML](#) provides components that enable highly optimized training and serving for the large problems in the world. Our solutions play a key role in >80% of Google revenue (e.g., by models across ads revenue) and account for a large fraction of overall ML resource usage. ~25% of TPU computation is through AdsML. > 2 EB of ML training data are stored in Woodshed.

Key components include:

- [Flogs](#): High-throughput ETL system handling online feature extraction from hundreds of raw data sources
- [Woodshed](#): Global, column-oriented storage system designed for ML, solving problems around efficiency, sharing features across many models, productionization, etc
- [AdBrain](#): Training system for large-scale, TF-based models. Enables online training of trained models like pCTR, pCVR, Ad Spam, and YouTube Viral.
- [Steelmill](#): Serving system for ML inference in Ads, focused on high-availability, high-performance serving.
- [LegoML](#): End-to-end platform with training focused on batch ML use cases in Ads. Examples: Unsupervised learning for AdSpam, Co-trained User embeddings across Shopping & Search models.

Woodshed has [Stacks Support Level 3](#). Flogs, AdBrain, and Steelmill are covered by a [Google 3 entry](#). LegoML is not currently covered in Stacks, but it is believed that it already meets the requirements.

There are three primary ways through which value is brought to Google by AdsML:

- i. Enable "all" revenue-critical ML applications in Ads
- ii. Contribute advanced ML infra technology/libraries back to Google (e.g., Datasync)
- iii. Leverage select AdsML components to support similar ML needs across other Products (e.g., Woodshed for Android Security)

3 Year Vision

Our 3-year vision is organized around three strategic directions that are well aligned with our goals: **Efficiency, Convergence and Privacy**.

Efficiency

Ads has experienced rapid growth in ML usage as we have introduced new products/features. The number of models in AdBrain has [grown 8X since April 2018](#). We expect to see continued growth in the ML space because of much needed ML innovation (e.g., language and image model formats and products). Because of this, there is a large opportunity for a strategic focus on "cost curve" for ML applications. This will allow us to continue to enable impact with a sustainable cost curve.

Key components include:

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