High-level Programming of Application Networks

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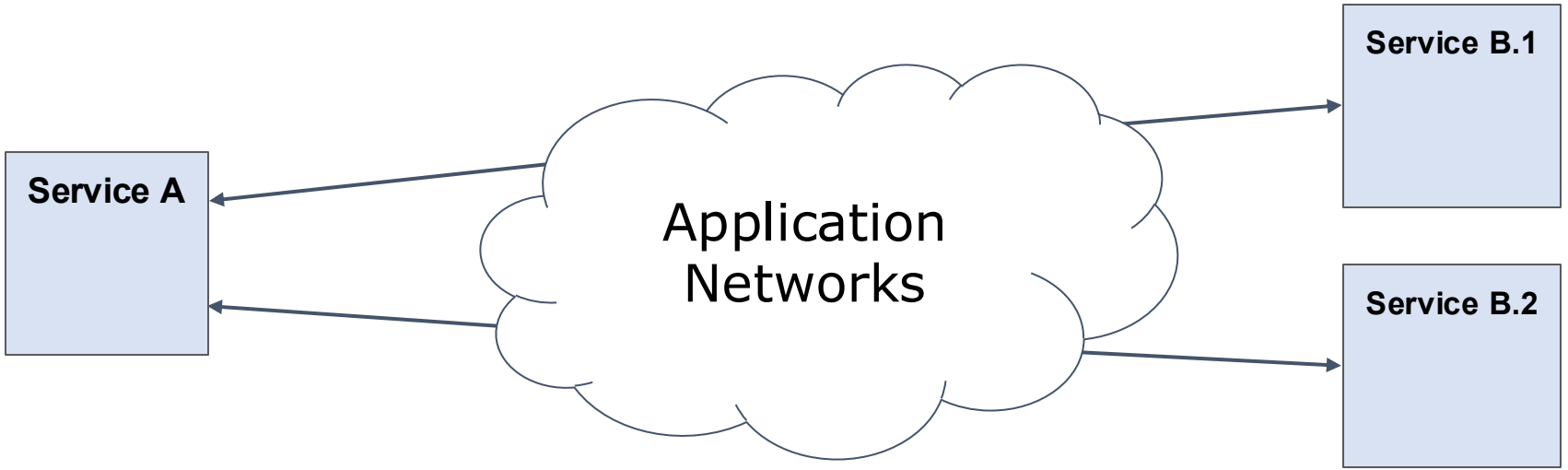
The Rise of Application Networks



Traffic Management

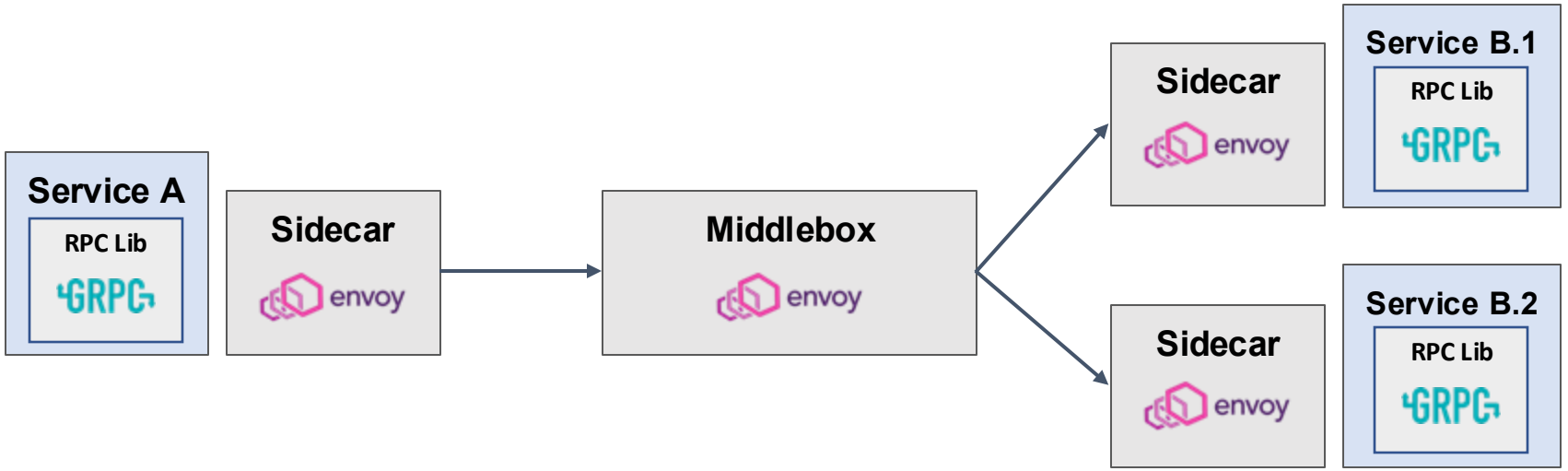
Policy Enforcement

Security

Observability

Application Network Functions (ANFs)

Current Approach: Service Meshes



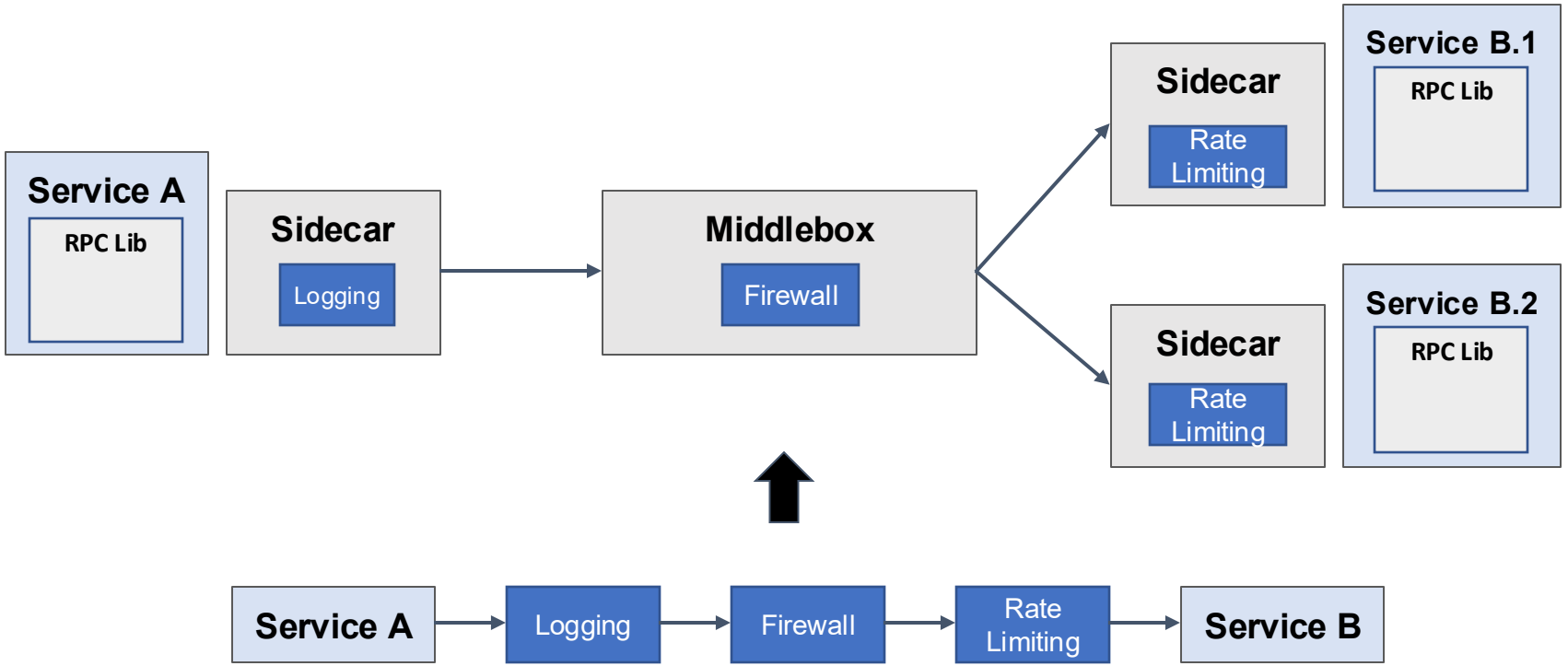
Istio

Google Cloud Anthos

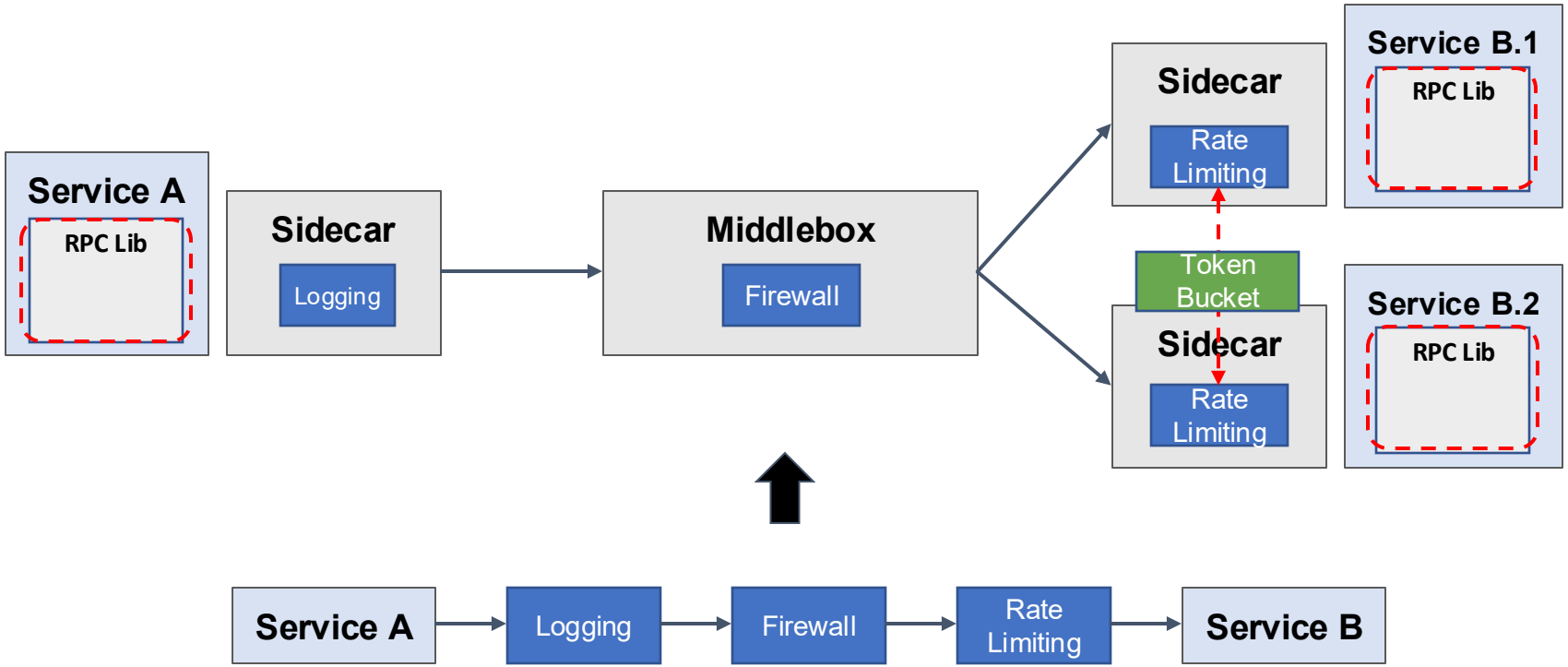
HashiCorp Consul

VMware Tanzu

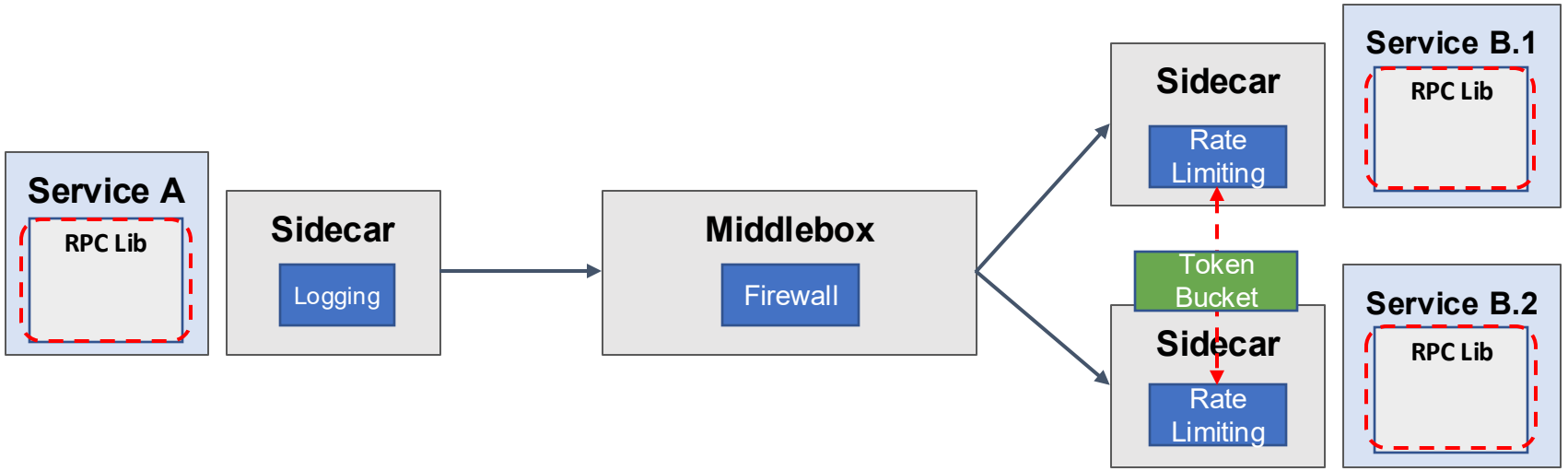
Challenge 1: High Developer Burden



Challenge 2: High Performance Overhead

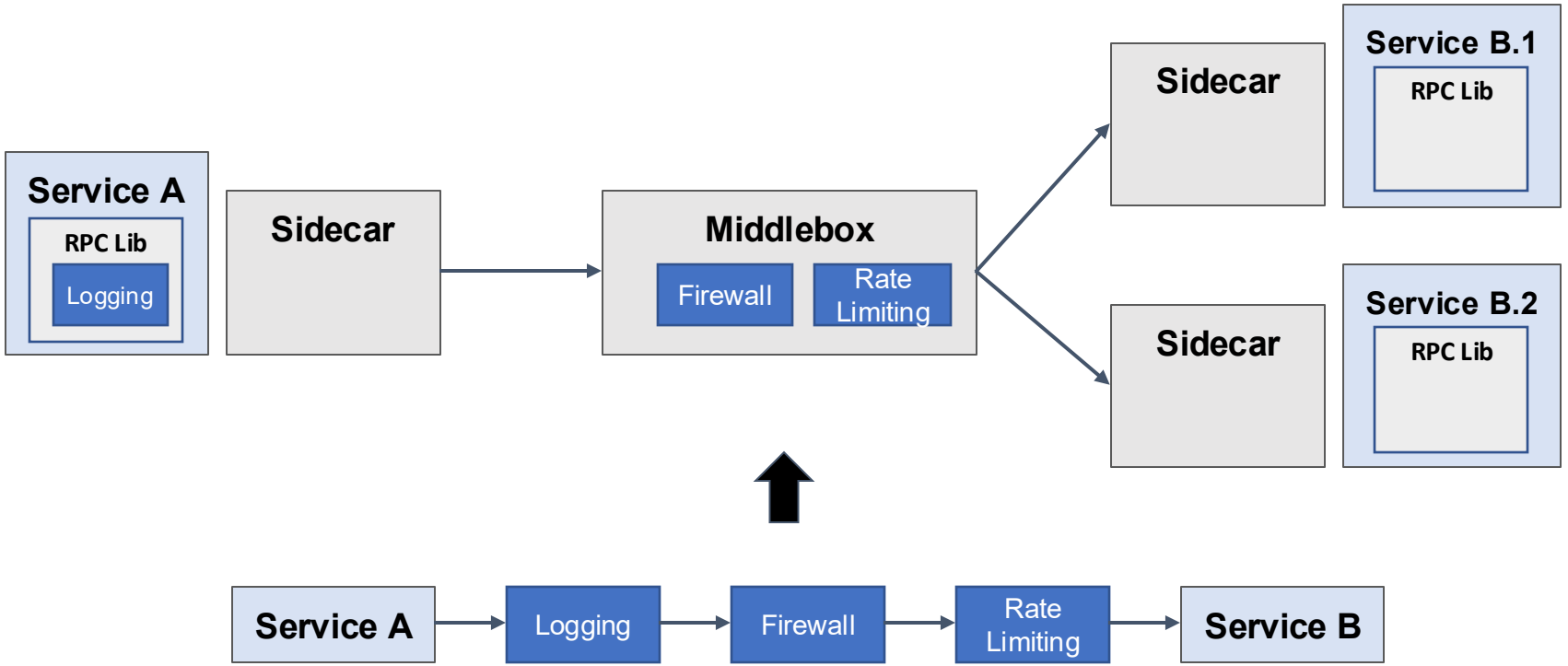


Challenge 2: High Performance Overhead



Service mesh can increase latency and CPU usage by 2-7X

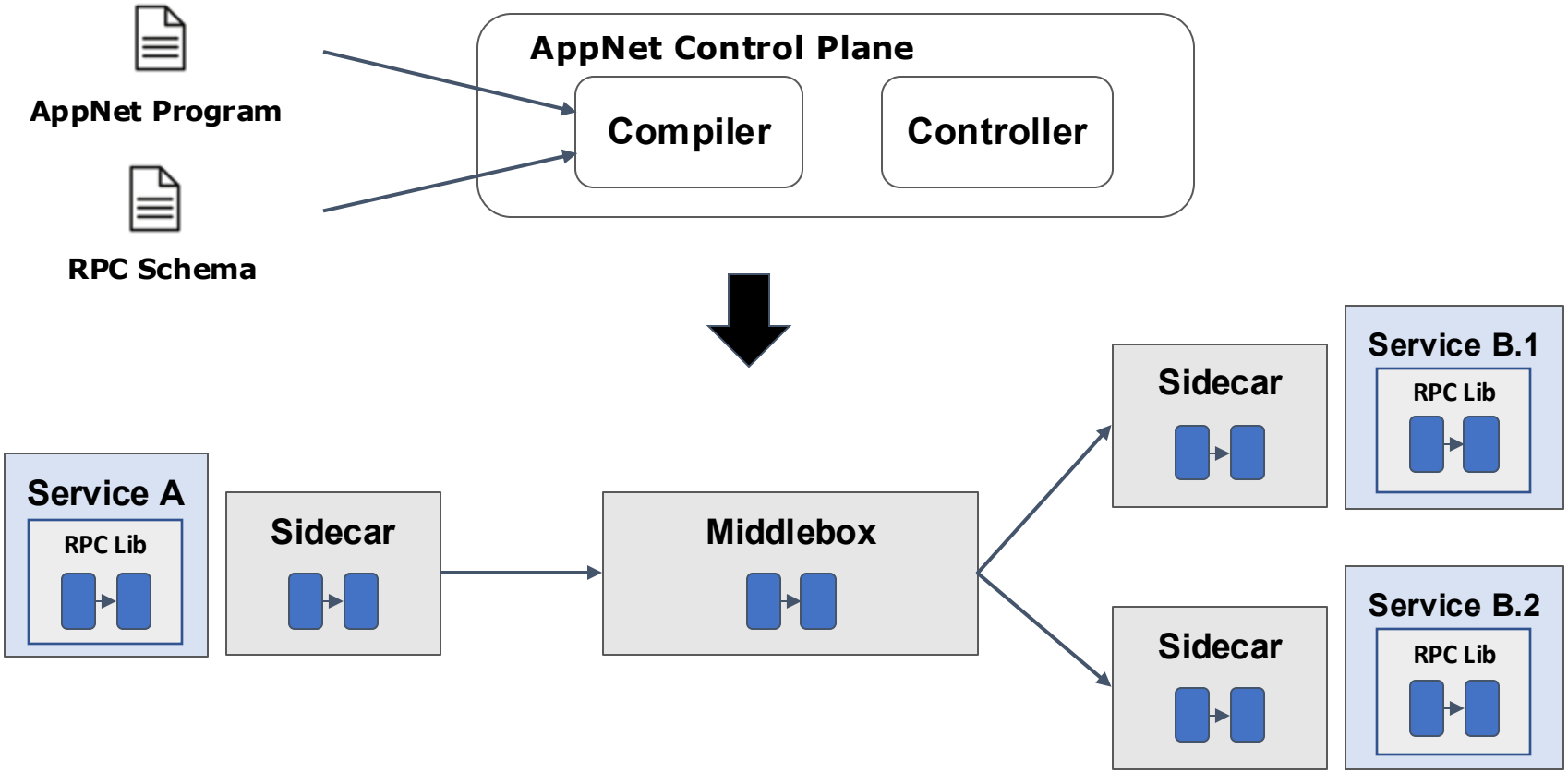
Challenge 2: High Performance Overhead



Goal

Make application networks **easy to build** and **highly performant**

AppNet: Decouples Specification from Implementation



AppNet Abstractions

- RPC Processing as a chain of elements

```
log()—>firewall()—>rate_limiting()
```

AppNet Abstractions

- RPC Processing as a chain of elements

- Generalized match-action rules over RPC field and state

```
req(rpc):
    username = get(rpc, 'username')          // Get username from RPC

    match get(firewall_rules, username):     // Get the permission from firewall_rules table
        'allowed' =>
            send(rpc)
        'denied' =>
            send(err('firewall'))
        None =>
            send(err('firewall'))
```

AppNet Abstractions

- RPC Processing as a chain of elements
- Generalized match-action rules over RPC field and state
- Shared state with configurable consistency level

See Paper for AppNet Grammar

$$
\begin{aligned}
\textit{Chain} ::= & \left[\begin{array}{l}
\textbf{client}: \textit{Element}^* \\
\textbf{any}: \textit{Element}^* \\
\textbf{server}: \textit{Element}^* \\
\textbf{pair}: (\textit{Element}, \textit{Element})^* \\
[\textbf{weak}]
\end{array}\right] \\
\textit{Element} ::= & \left[\begin{array}{l}
\textbf{state}: \textit{Decl}^* \\
\textbf{init}(\textit{Var}^*): \textit{Assign}^* \\
\textbf{req}(\textit{Var}): \textit{Action}^* \ [\textit{MatchAction}] \\
\textbf{resp}(\textit{Var}): \textit{Action}^* \ [\textit{MatchAction}]
\end{array}\right] \\
\textit{Decl} ::= & \ \textit{Var}\ [\textbf{shared}\ [\textbf{weak}\ [\textbf{sum}]]] \\
\textit{MatchAction} ::= & \ \textbf{match}(\textit{Expr})\ \textit{Case}^+\ [\texttt{'*'} \Rightarrow \textit{Action}^+] \\
\textit{Case} ::= & \ \textit{Literal} \Rightarrow \textit{Action}^+ \\
\textit{Action} ::= & \ \textit{Assign} \mid \textit{Send} \mid \textit{Foreach} \mid \textit{Return} \\
\textit{Assign} ::= & \ \textit{Var} = \textit{Expr} \mid \textbf{set}(\textit{Var}, \textit{Expr}^+, \textit{Expr}) \\
\textit{Send} ::= & \ \textbf{send}(\textit{Message}, \textit{Channel})
\end{aligned}
$$

$$
\begin{aligned}
\textit{Foreach} ::= & \ \textbf{foreach}(\textit{Var}, \textit{LambdaFunc}) \\
\textit{Return} ::= & \ \textbf{return}\ [\textit{Expr}] \\
\textit{Message} ::= & \ \textit{Var} \mid \texttt{'error'} \\
\textit{Channel} ::= & \ \textbf{down} \mid \textbf{up} \mid \textit{Var} \\
\textit{Expr} ::= & \ \textit{Literal} \mid \textit{Var} \mid \textbf{get}(\textit{Var}, \textit{Expr}^+ [, \textit{LambdaFunc}]) \\
& \mid \text{BuiltinFunc}(\textit{Expr}^*) \\
\textit{LambdaFunc} ::= & \ \textbf{lambda}(\textit{Var}+) \Rightarrow \textit{Action}^*\ [\textit{MatchAction}] \\
\textit{Var} \in & \ (\text{set of variable names}) \\
\textit{Literal} \in & \ (\text{literal values, e.g. } 0.1, 42, \textbf{true})
\end{aligned}
$$

AppNet Compiler

- Goal: Find a high-performance configuration while preserving semantics
  - Platform (gRPC, Envoy, …)
  - Location (caller, callee, middlebox)
  - Execution Order

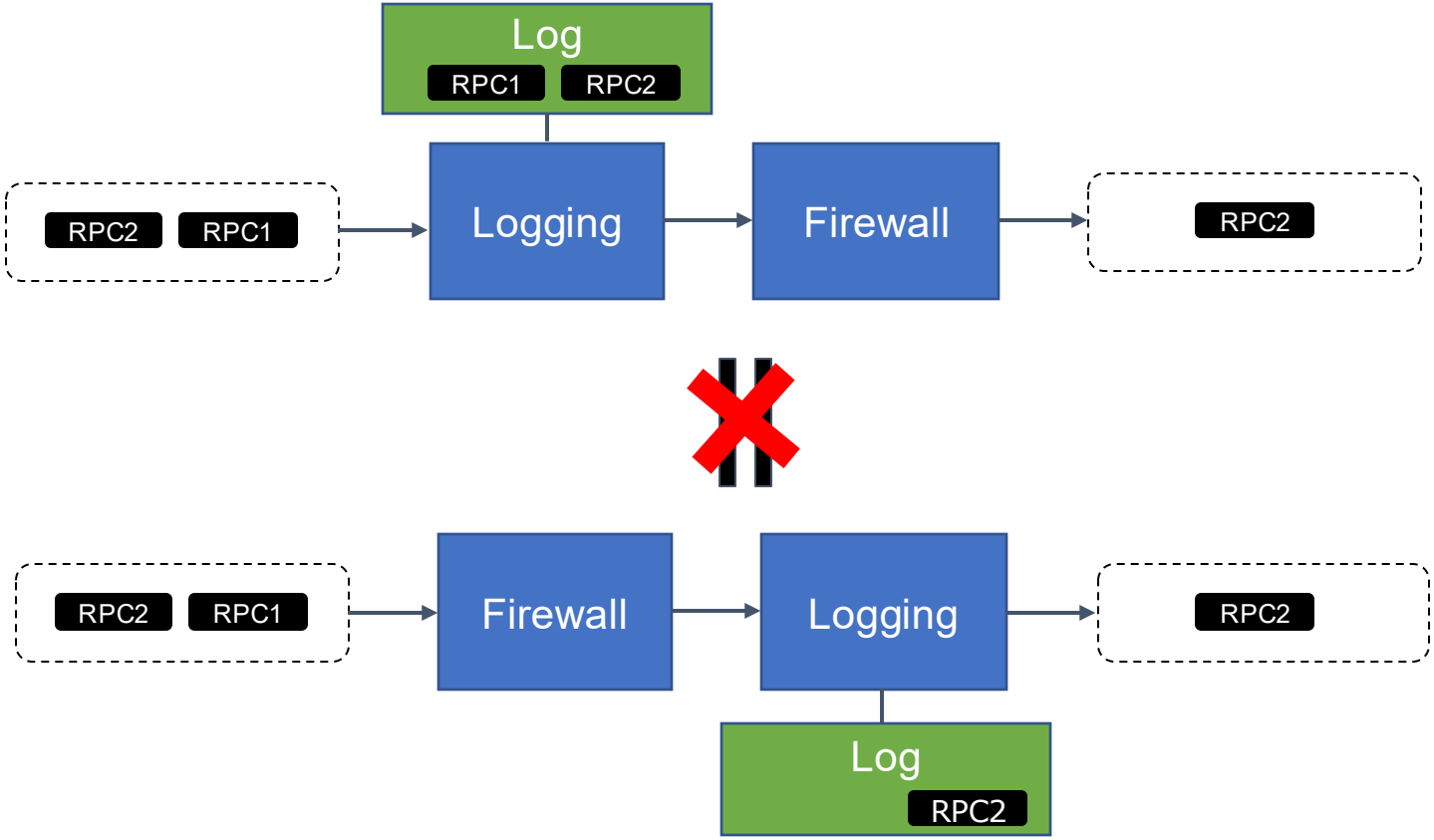
AppNet Compiler

- Goal: Find a high-performance configuration while preserving semantics

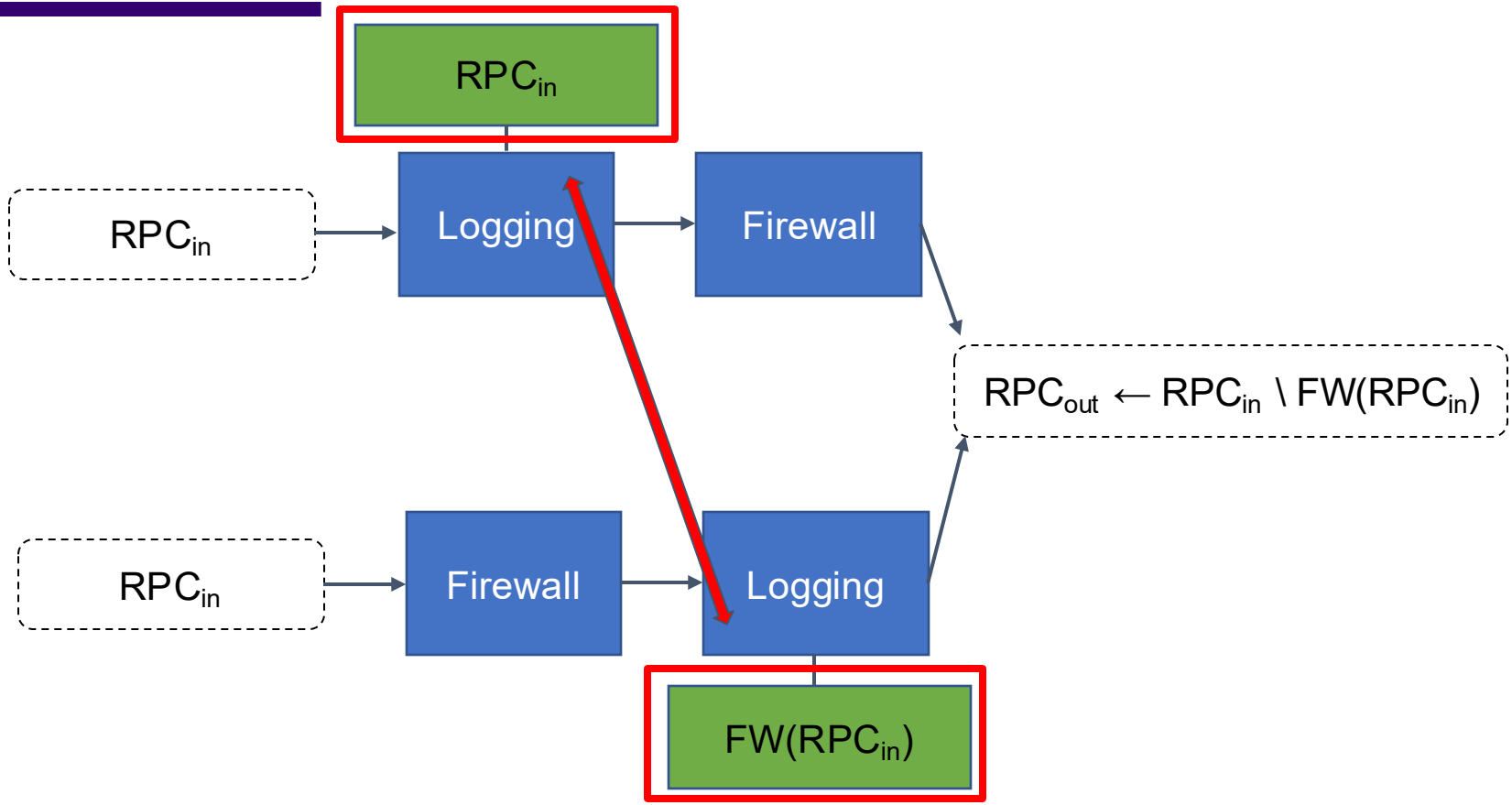
Challenges

- Preserve semantic equivalence
  - Some ANFs are stateful
  - Reordering or relocating ANFs may change behavior
- Huge search space
  - Many platform + location + order permutations

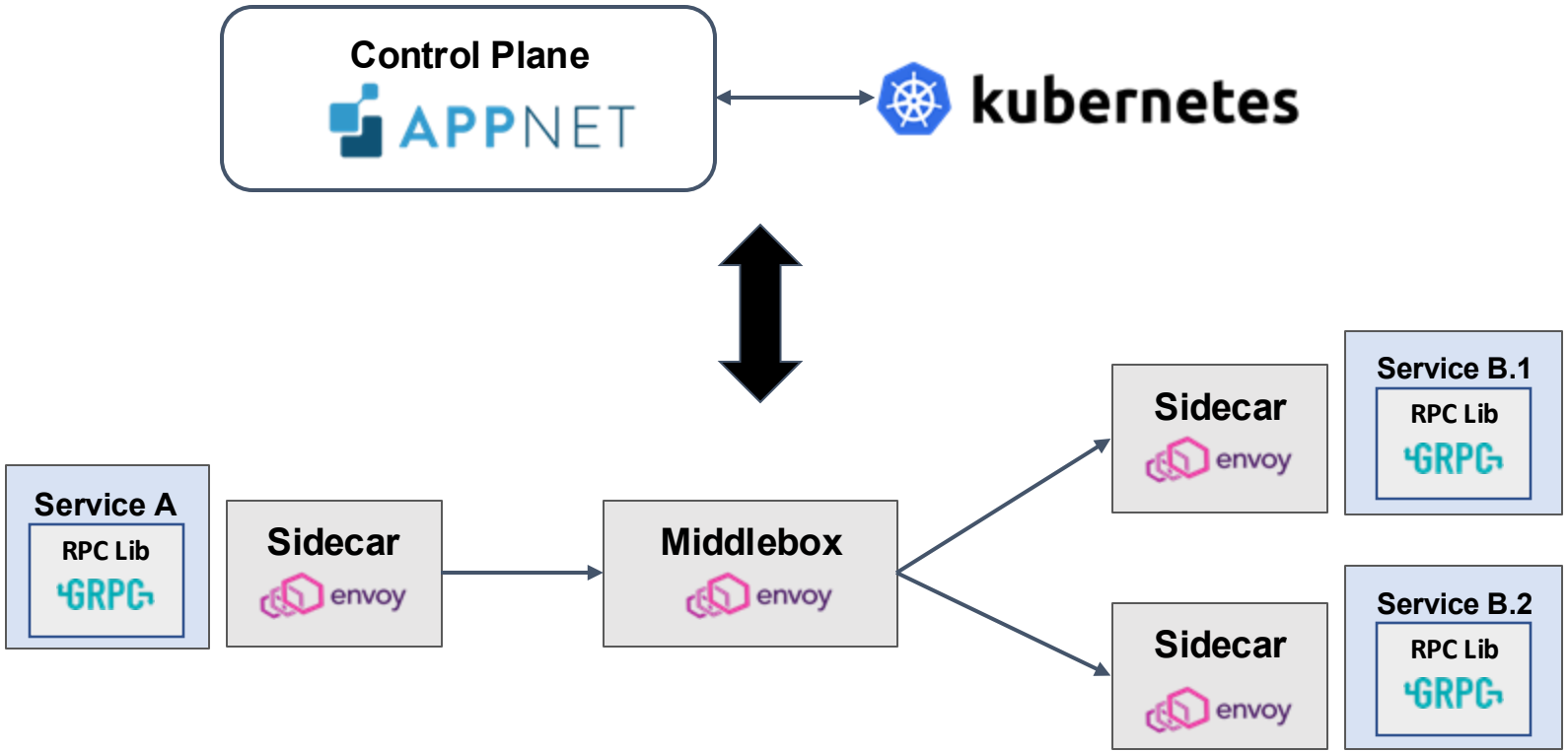
Example: Semantic Inequivalence



Equivalence Checking: Symbolic Execution



Implementation



Evaluation Questions

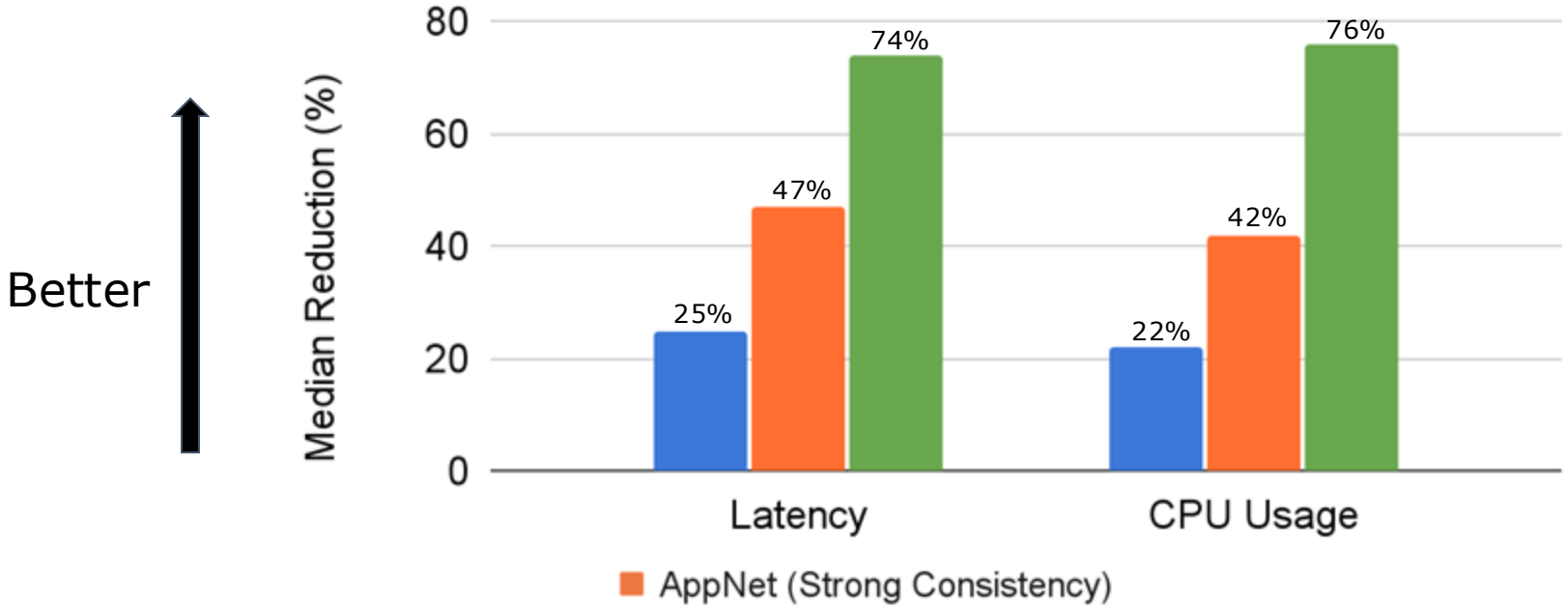
- **Expressiveness**
  - Can AppNet easily express common ANFs?
- **Performance**
  - Can AppNet reduce overhead and improve application performance?

AppNet Simplifies ANF Development

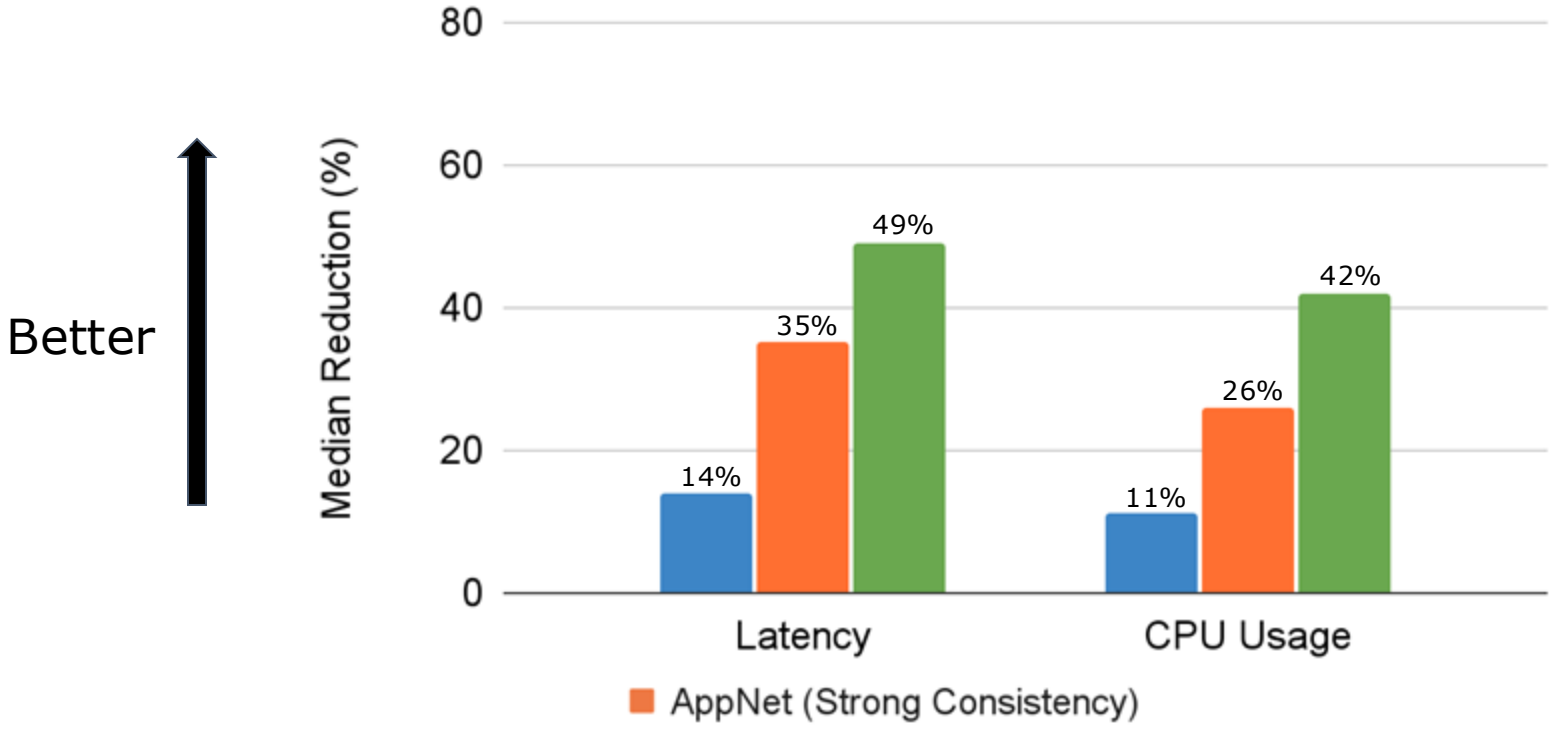
- 12 common ANFs can be implemented in 7-28 LoC
- Meta’s ServiceRouter and Google’s Prequal in < 100 LoC

Reduce LoC by 5–60× compared to manual implementation

AppNet Reduces RPC Processing Overhead



AppNet Improves Application Performance



APPNET

- Application networks today are hard to use and have poor performance
- AppNet **decouples specification from implementation**
  - Auto-generates efficient implementations across platforms
  - Optimizes performance based on platform and user policy

https://github.com/appnet-org/appnet

https://appnet.wiki/