High-level Programming of Application Networks

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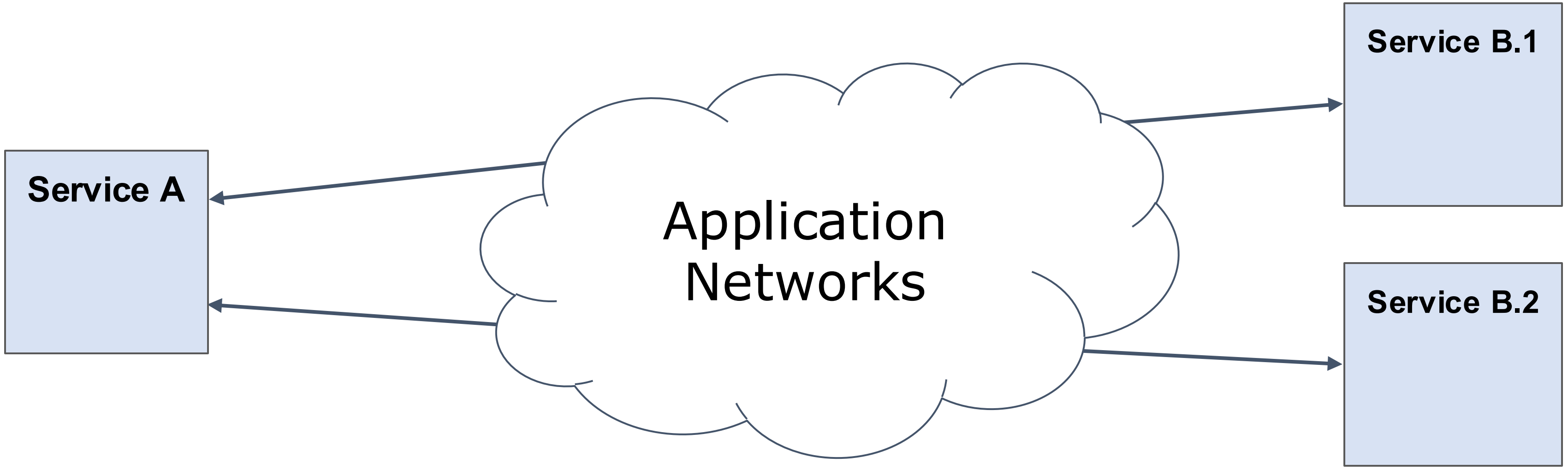
The Rise of Application Networks



Traffic Management

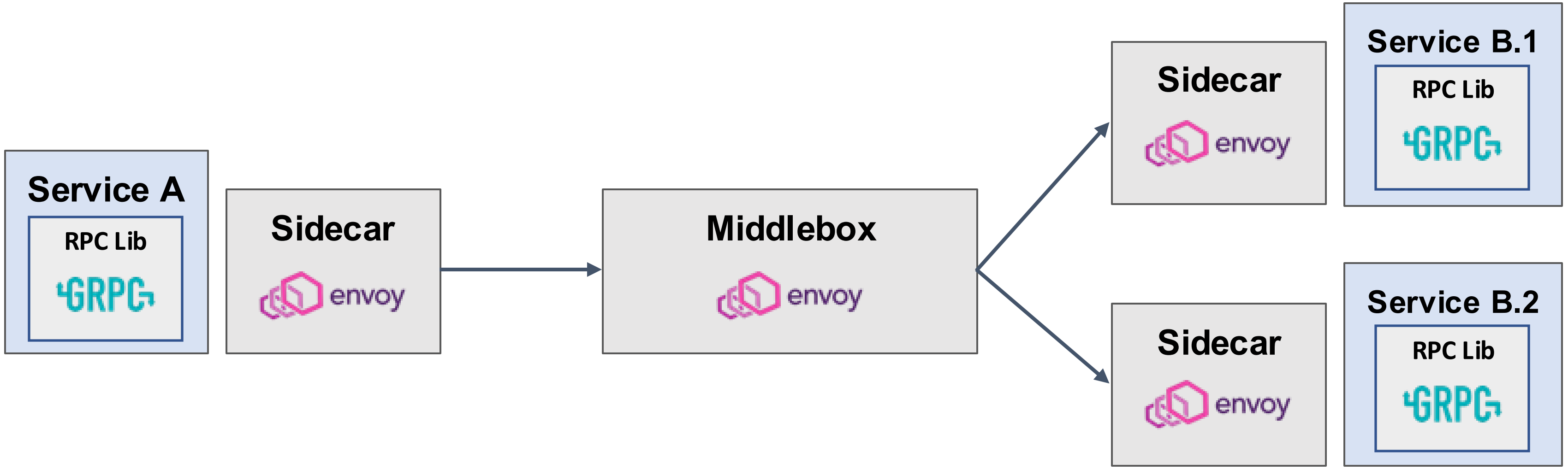
Policy Enforcement

Security

Observability

Application Network Functions (ANFs)

Current Approach: Service Meshes



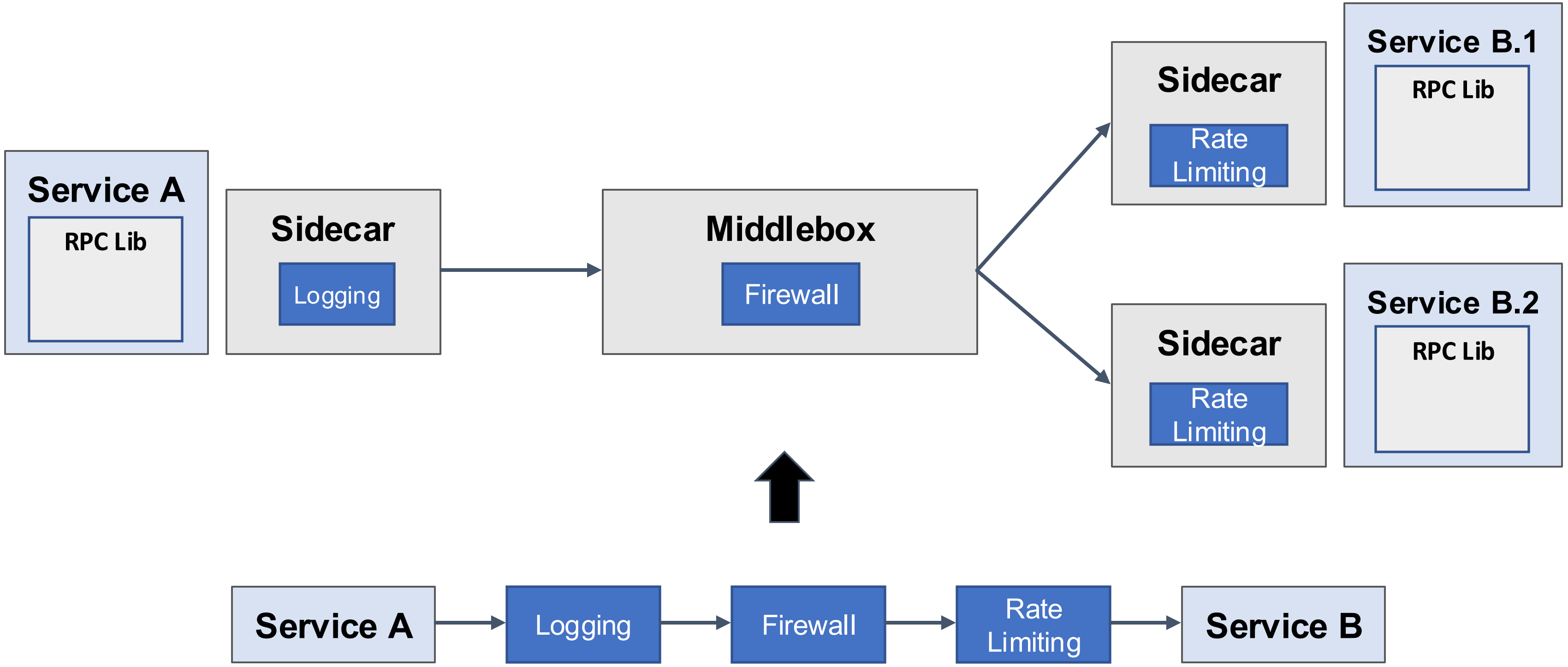
Istio

Google Cloud Anthos

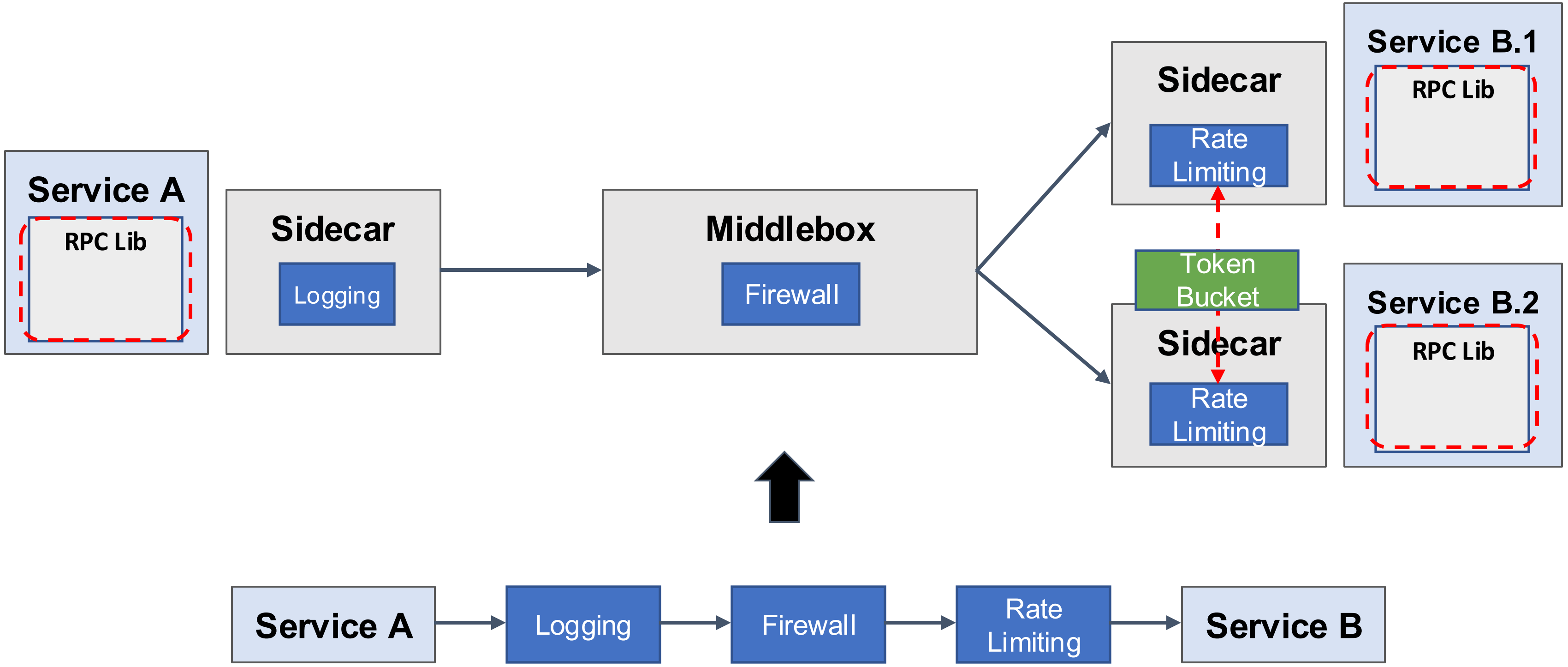
HashiCorp Consul

VMware Tanzu

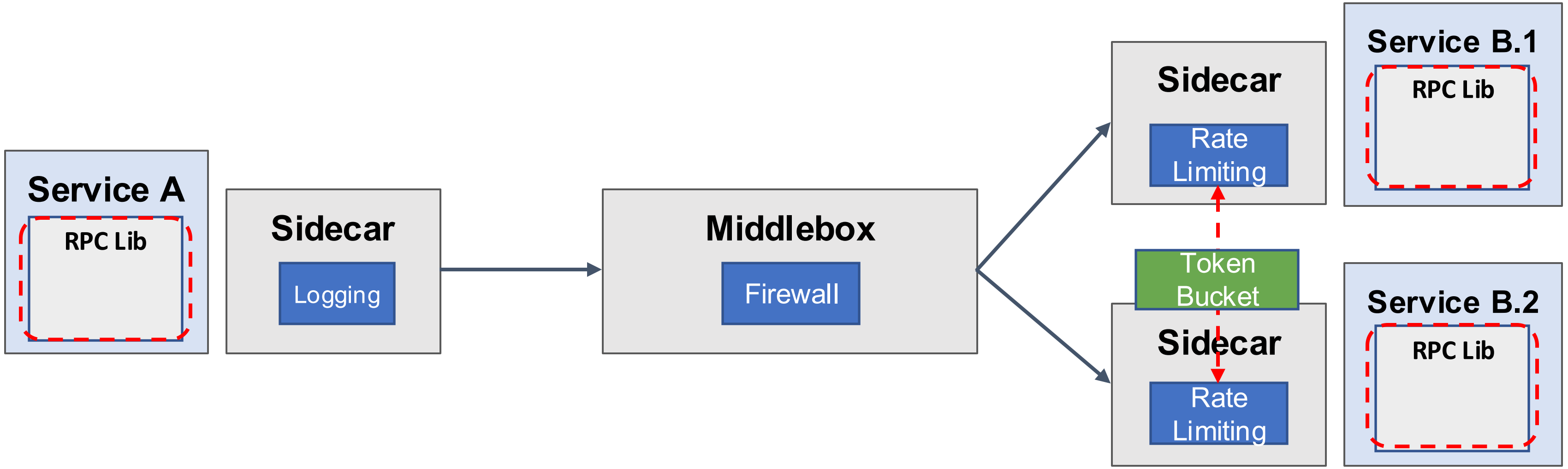
Challenge 1: High Developer Burden



Challenge 2: High Performance Overhead

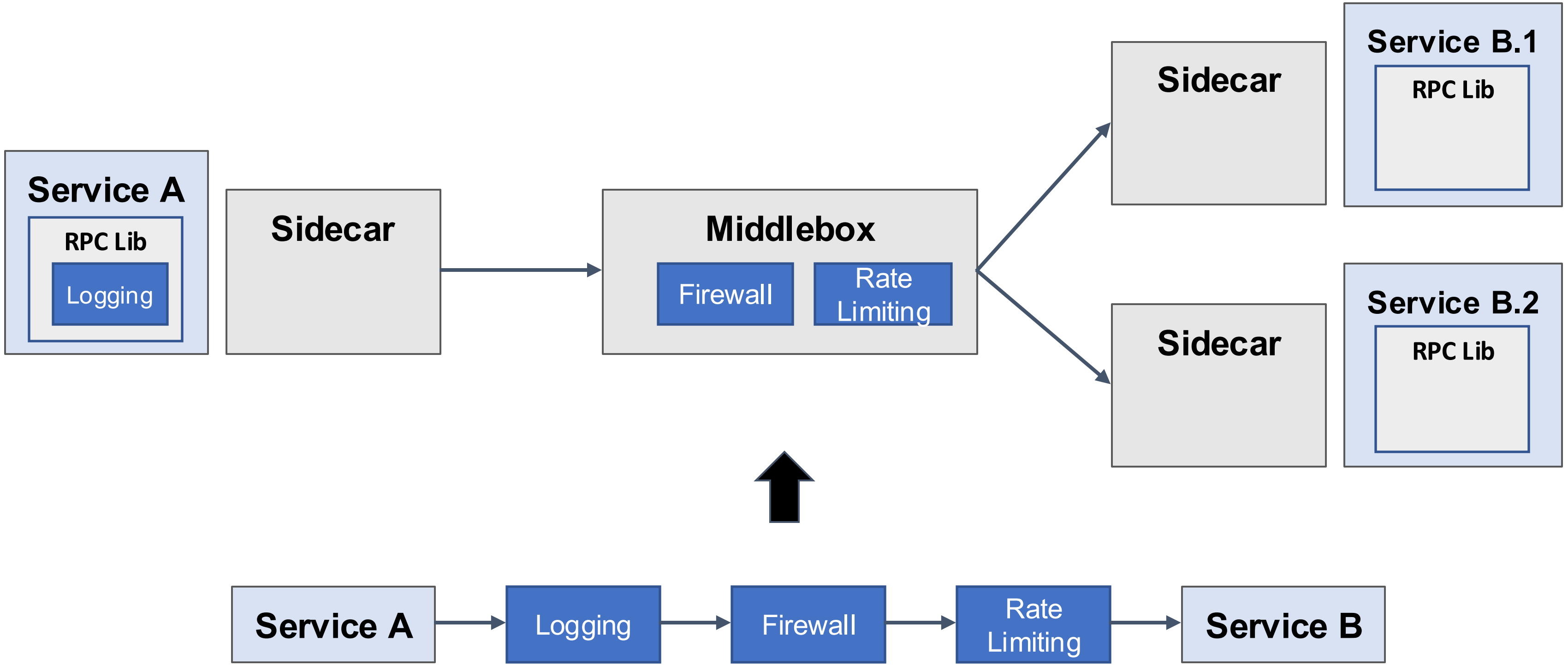


Challenge 2: High Performance Overhead



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

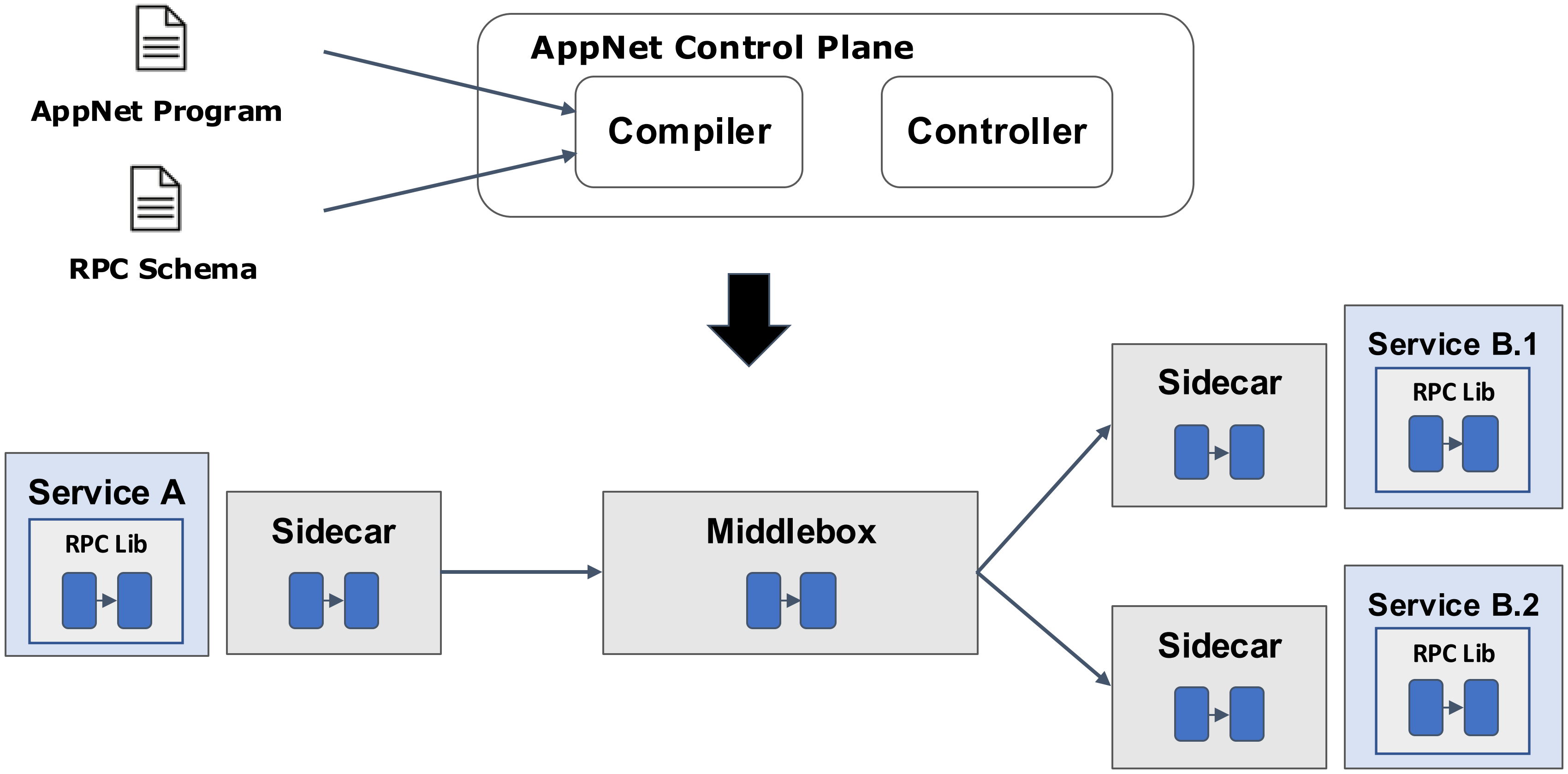
Challenge 2: High Performance Overhead



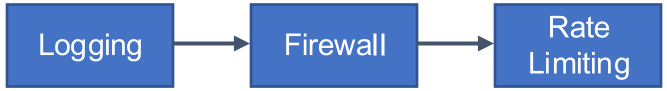
Goal

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

AppNet: Decouples Specification from Implementation



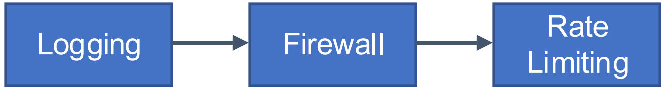
AppNet Abstractions



- RPC Processing as a chain of elements

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

AppNet Abstractions



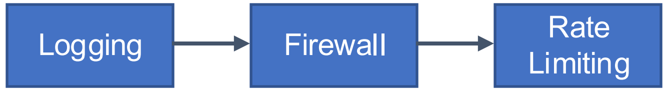
- RPC Processing as a chain of elements

- 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

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

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

AppNet Compiler

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

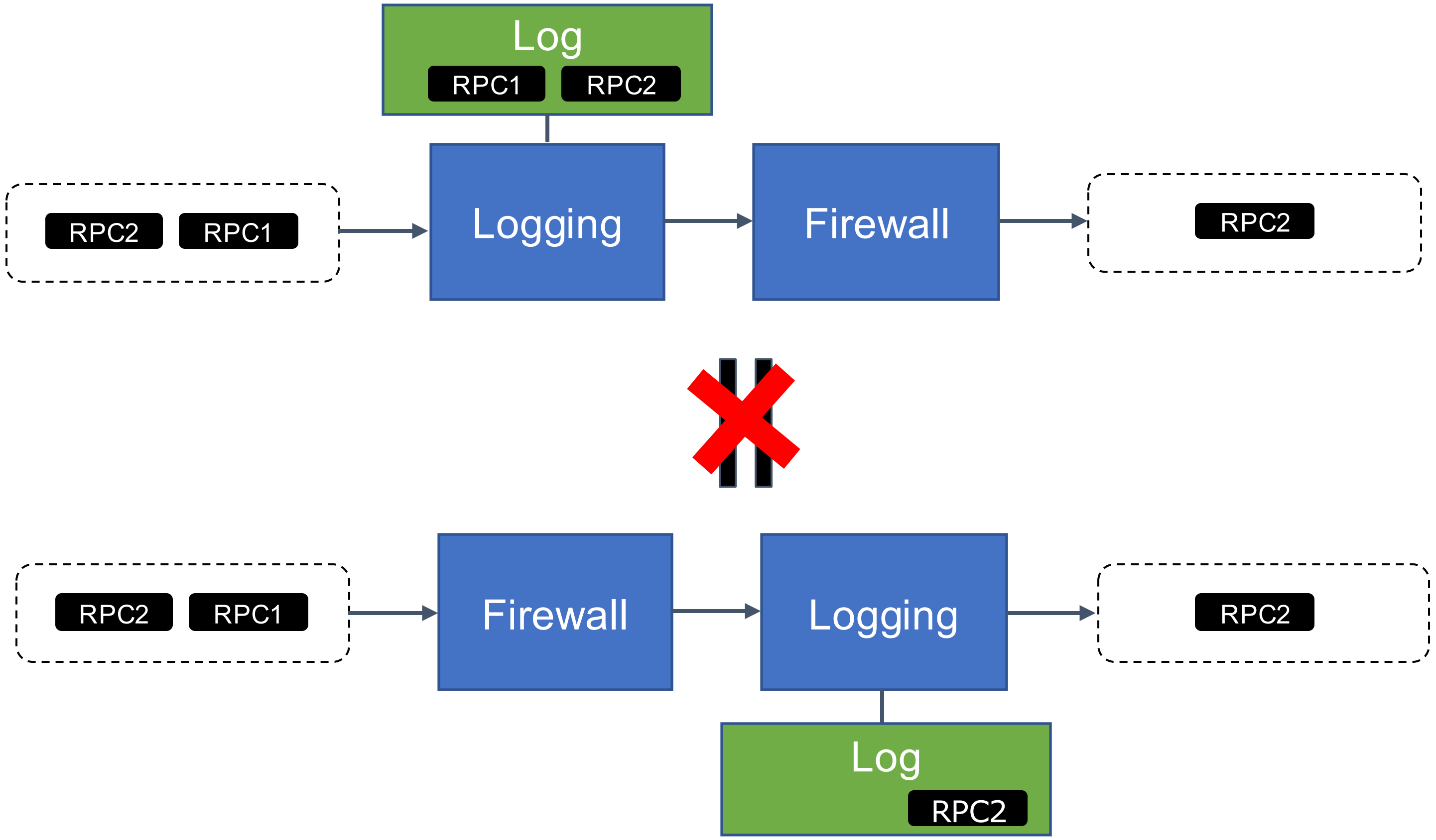
AppNet Compiler

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

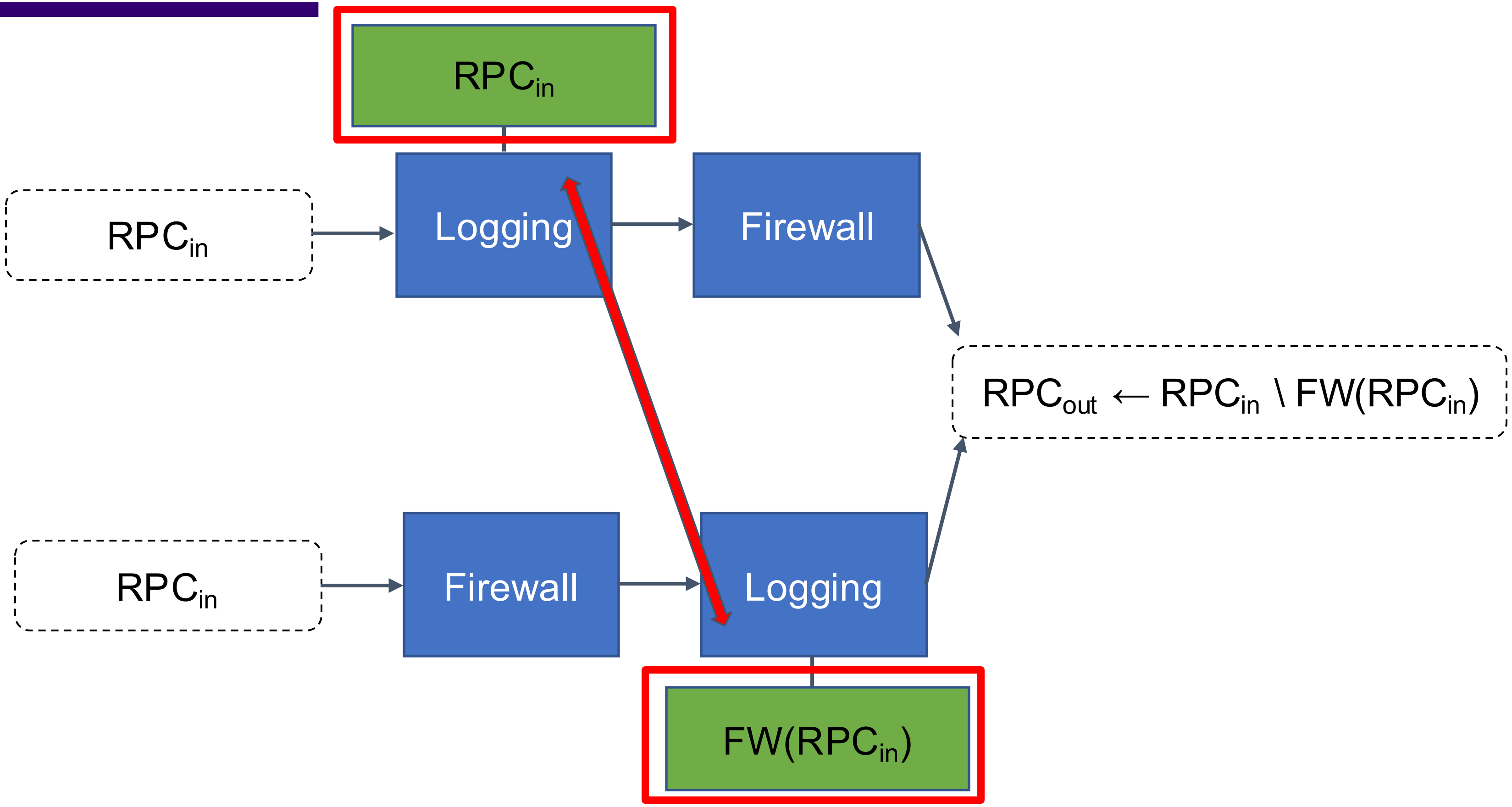
Challenges

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

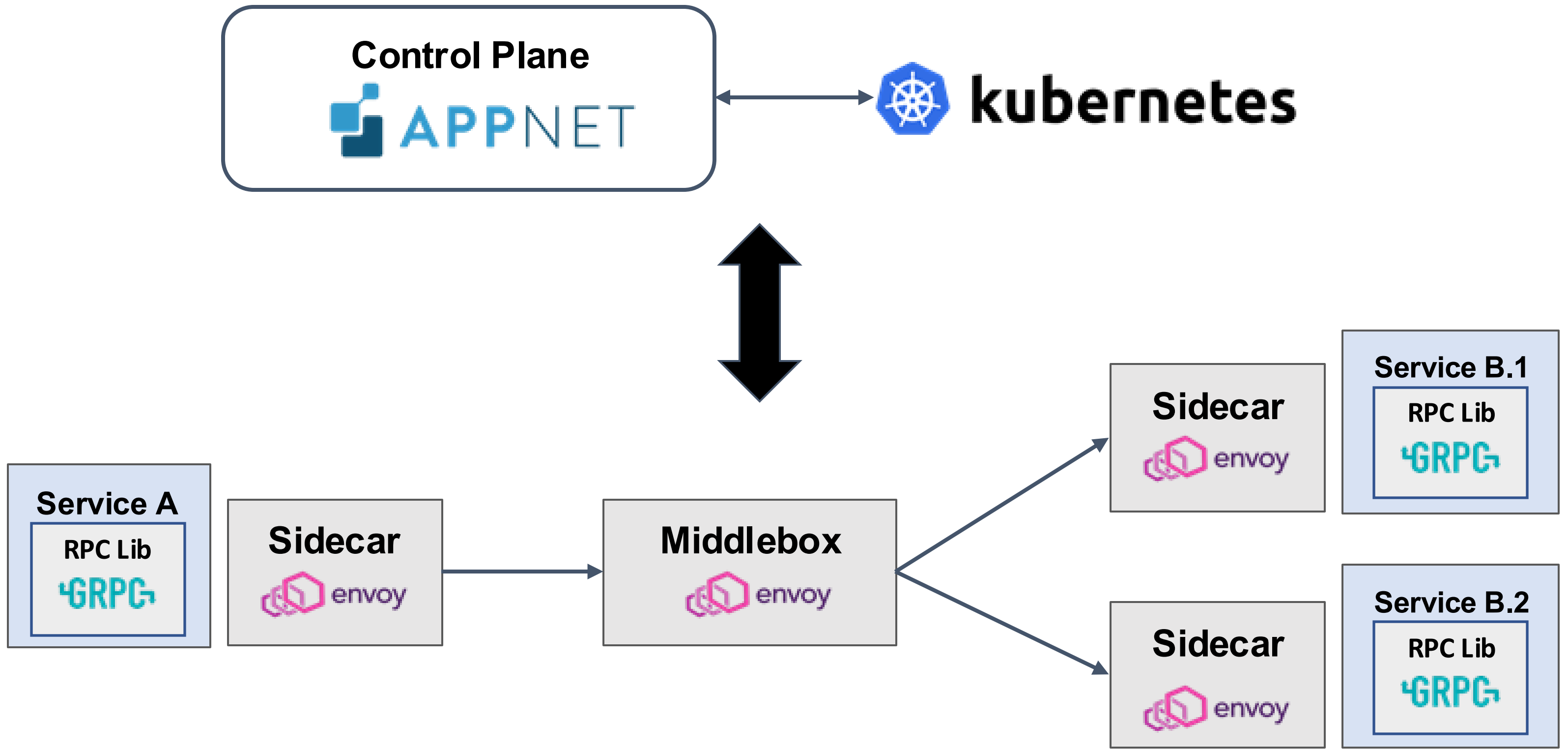
Example: Semantic Inequivalence



Equivalence Checking: Symbolic Execution



Implementation



Evaluation Questions

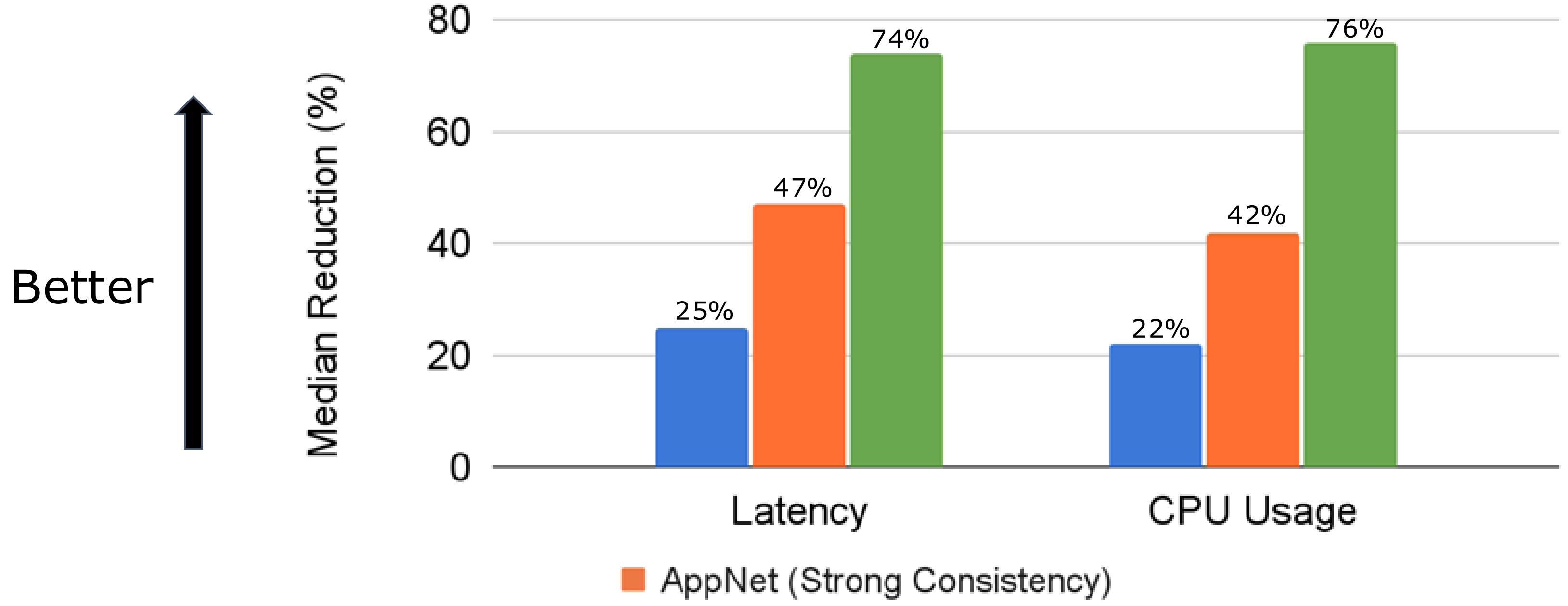
- **Expressiveness**
  - Can AppNet easily express common ANFs?
- **Performance**
  - Can AppNet reduce overhead and improve application performance?

AppNet Simplifies ANF Development

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

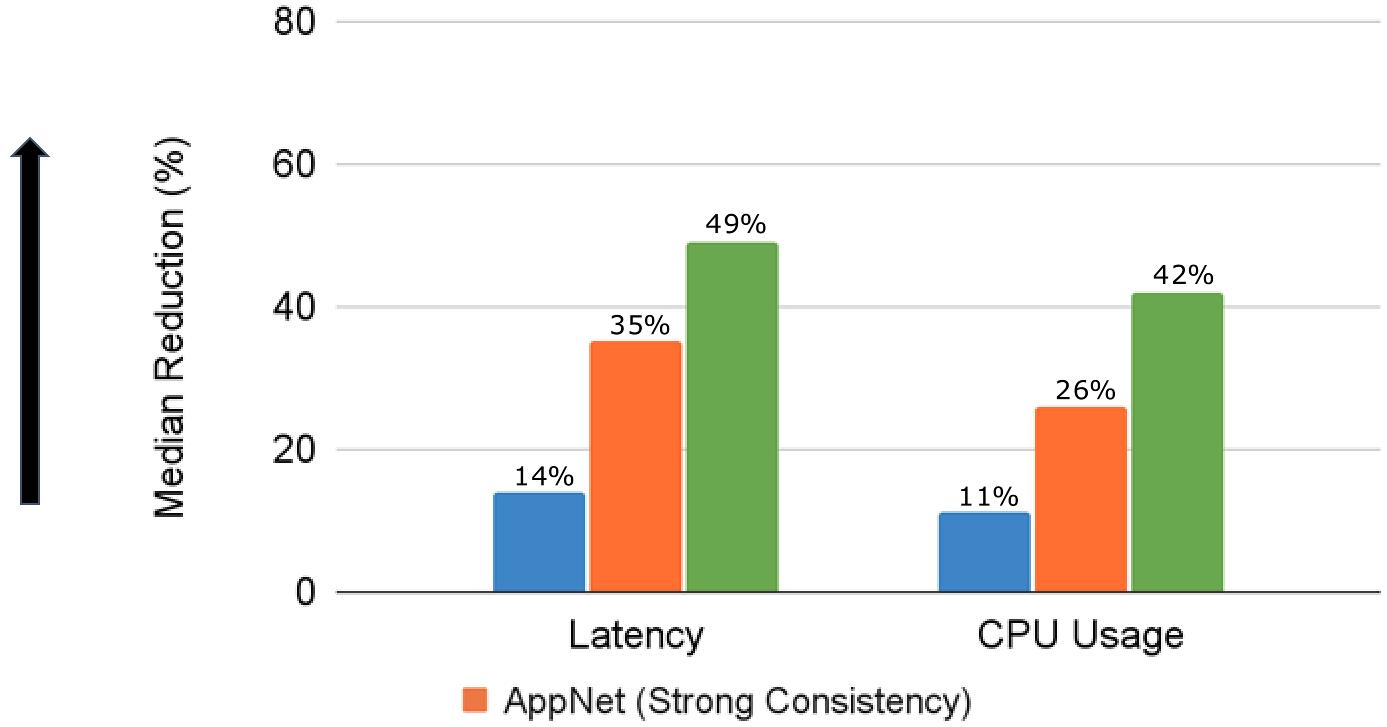
Reduce LoC by 5–60× compared to manual implementation

AppNet Reduces RPC Processing Overhead



AppNet Improves Application Performance

Better



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/