Distributed Procedure Call

A Primitive for High-Performance “Multi-Hop” Communication

Collin Lee [June 12, 2020]

PLATFORMLAB

What communication framework should I use?

RPC is the de facto standard.
Can we do better?

Distributed Procedure Call

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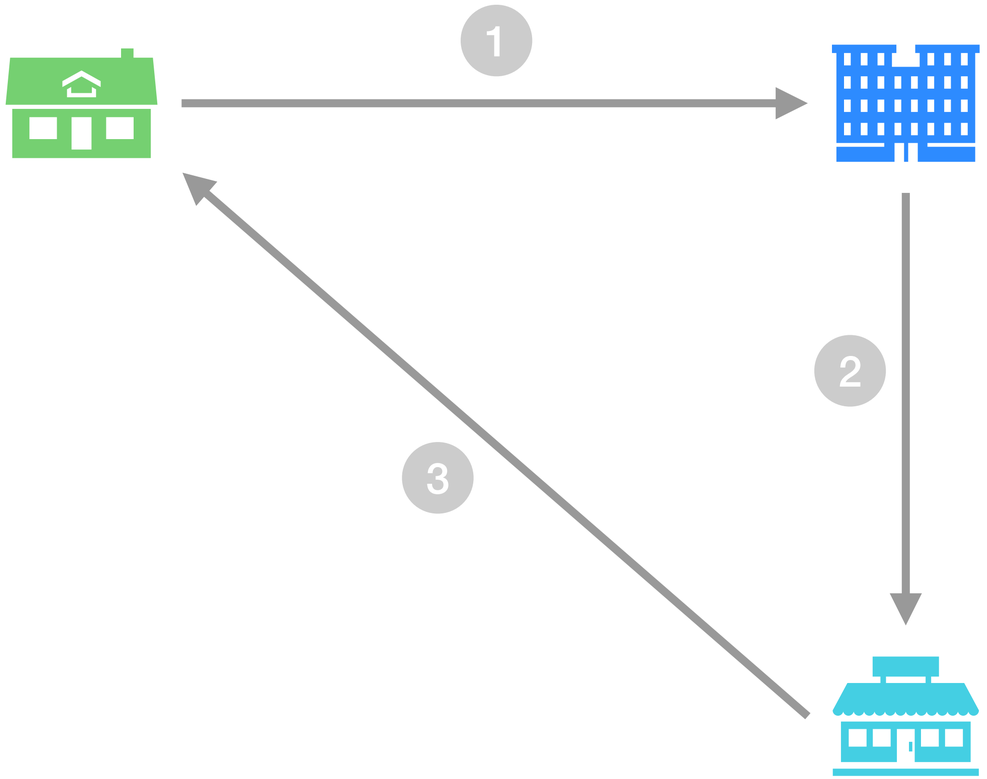
Distributed Procedure Call (DPC)

A Primitive for High-Performance “Multi-Hop” Communication

- Support *multi-hop* communication pattern
  - Eliminates or moves messages out of the critical path
- Complete reference DPC framework implementation, *Roo*
  - Lightweight for use in low-latency environments
  - Solutions for detecting DPC completion and DPC failure
- Lower latency than RPC in many use cases
  - 20-59% reduction in end-to-end latency

Example “Complex” Distributed Service

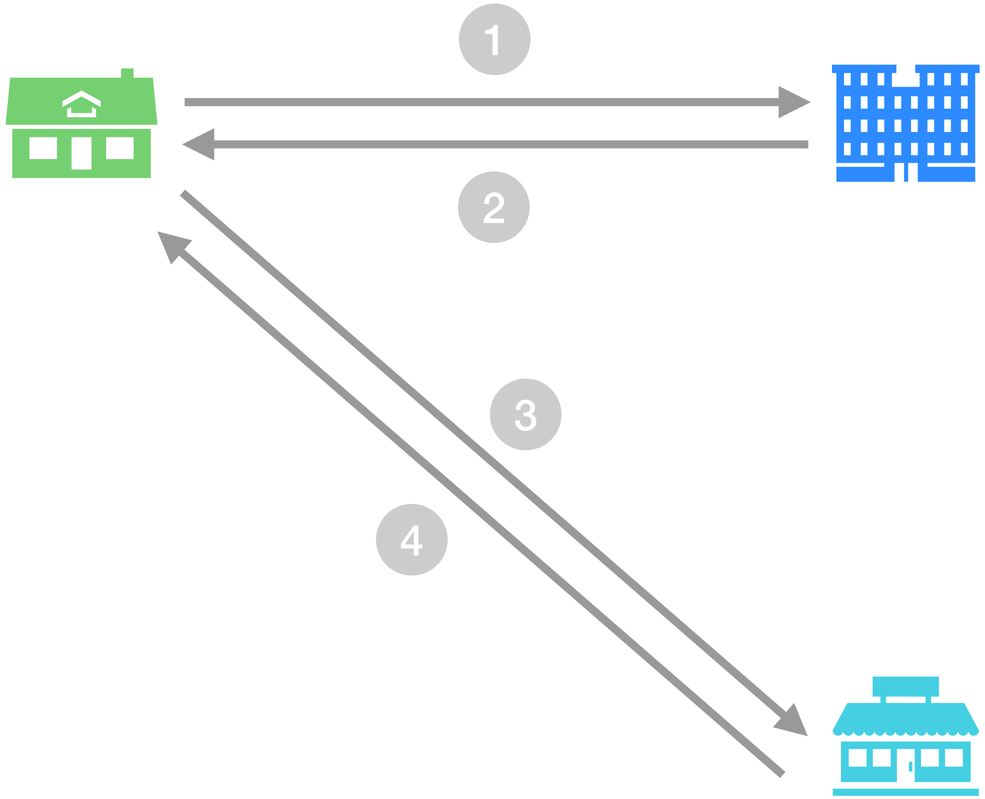
A real life *multi-hop* example



- **Complex service**: Request processing requires visiting multiple consecutive service nodes
- Need more ***supplies*** from the **store**
- Need ***membership card*** from **office**
- Execution of `getToiletPaper`
  1. Go to **office** to get ***membership card***
  2. Go to **store** to get ***supplies***
  3. Return **home**

Example “Complex” Distributed Service

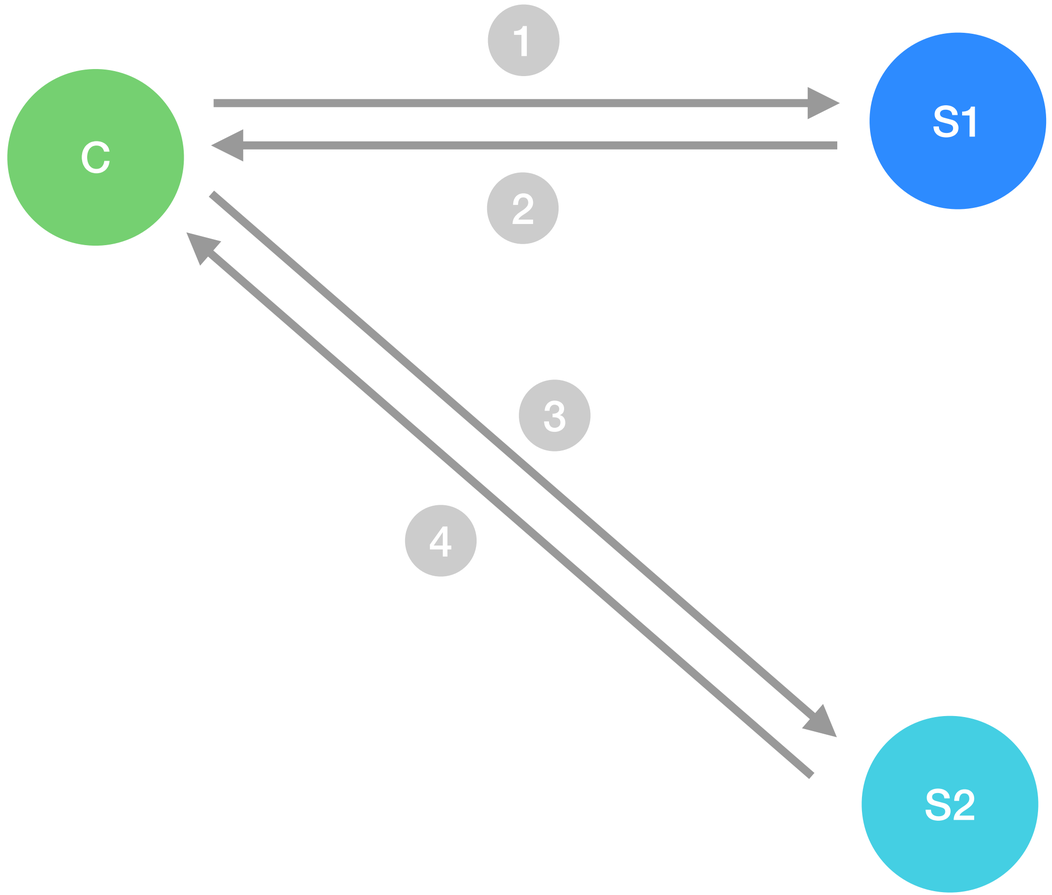
Why not go home between trips to office and store?



- Need more *supplies* from the store
- Need *membership card* from office
- Execution of `getToiletPaper`
  1. Go to office to get *membership card*
  2. Return home
  3. Go to store to get *supplies*
  4. Return home

Example RPC Pattern

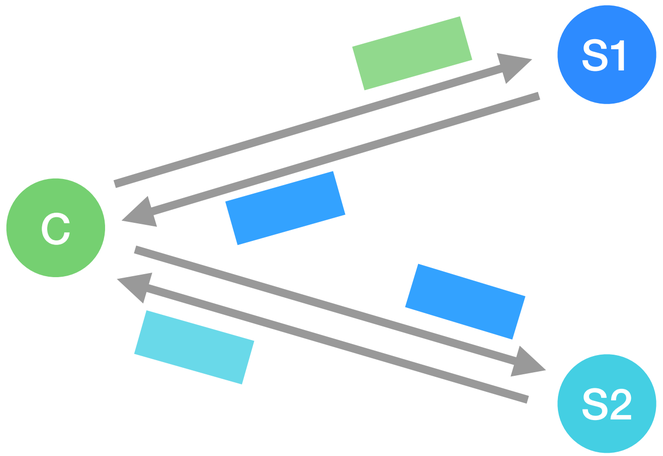
Key-value store lookup by secondary index



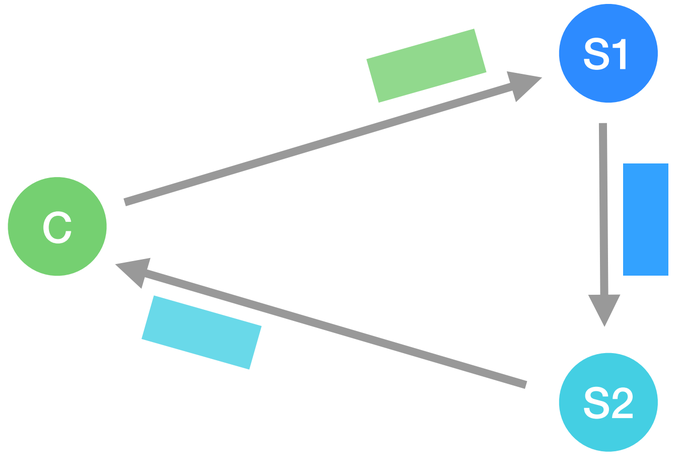
- Need ***object*** from the **object store**
- Need ***index info*** from **index server**
- Execution of `getObjectByIndex`
  1. Go to **index server** to get ***index info***
  2. Return to **client**
  3. Go to **object store** to get ***object***
  4. Return to **client**

RPC vs Multi-Hop Pattern

RPC pattern can be less efficient than Multi-Hop pattern



(a) RPC Pattern

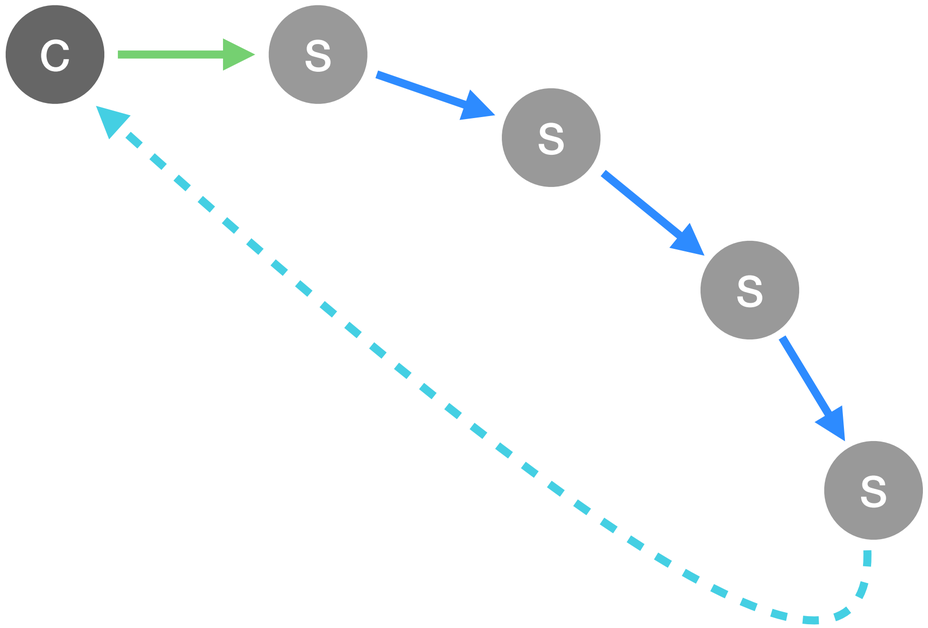


(b) Multi-Hop Pattern

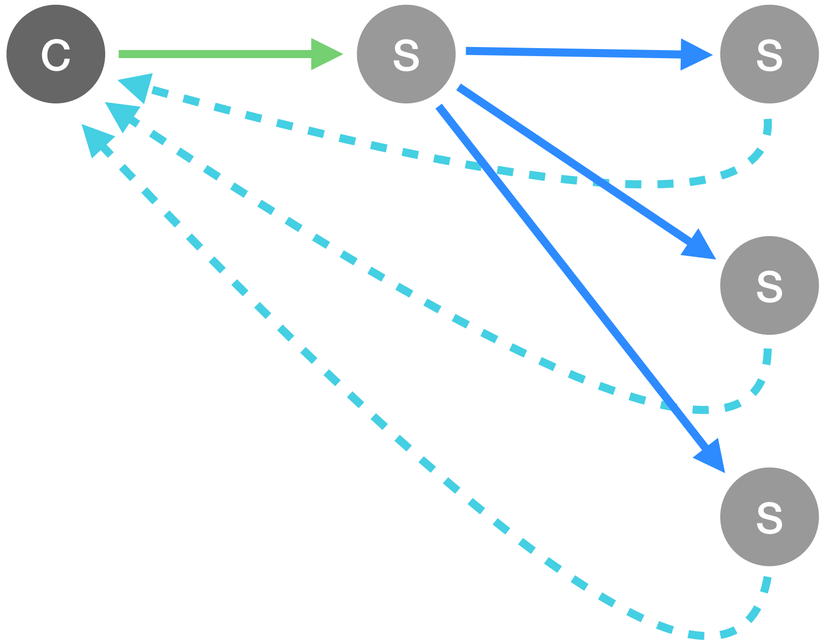
- Increased end-to-end latency (2.0 RTT vs 1.5 RTT)
- Increased message processing ( is sent and handled twice vs once)
- Performance impact grows with the number of hops and messages

Features of the DPC Abstraction

The two features needed to support any multi-hop pattern



Direct Communication (hops)



Parallel Invocation (fan-out)

The DPC Abstraction

Supporting the multi-hop pattern with a simple abstraction

Similarities with RPC

- Request-Response model:
  - **requests** sent to DPC servers to be processed
  - **responses** sent and received by DPC clients
- Associates request and response messages

Differences from RPC

- **Delegated requests (multi-hop):**
  - DPC servers can delegate a request to other servers
- **Multiple requests and responses (fan-out)**:
  - DPC clients and servers can send multiple requests
  - DPC clients can receive multiple responses

The DPC API

Client API

`send_request()`

Send a **request** to a server

`receive_response()`

Return a **response**, if available

`wait()`

Block until all responses have arrived

Server API

`receive()`

Receive **request**, if available

`delegate()`

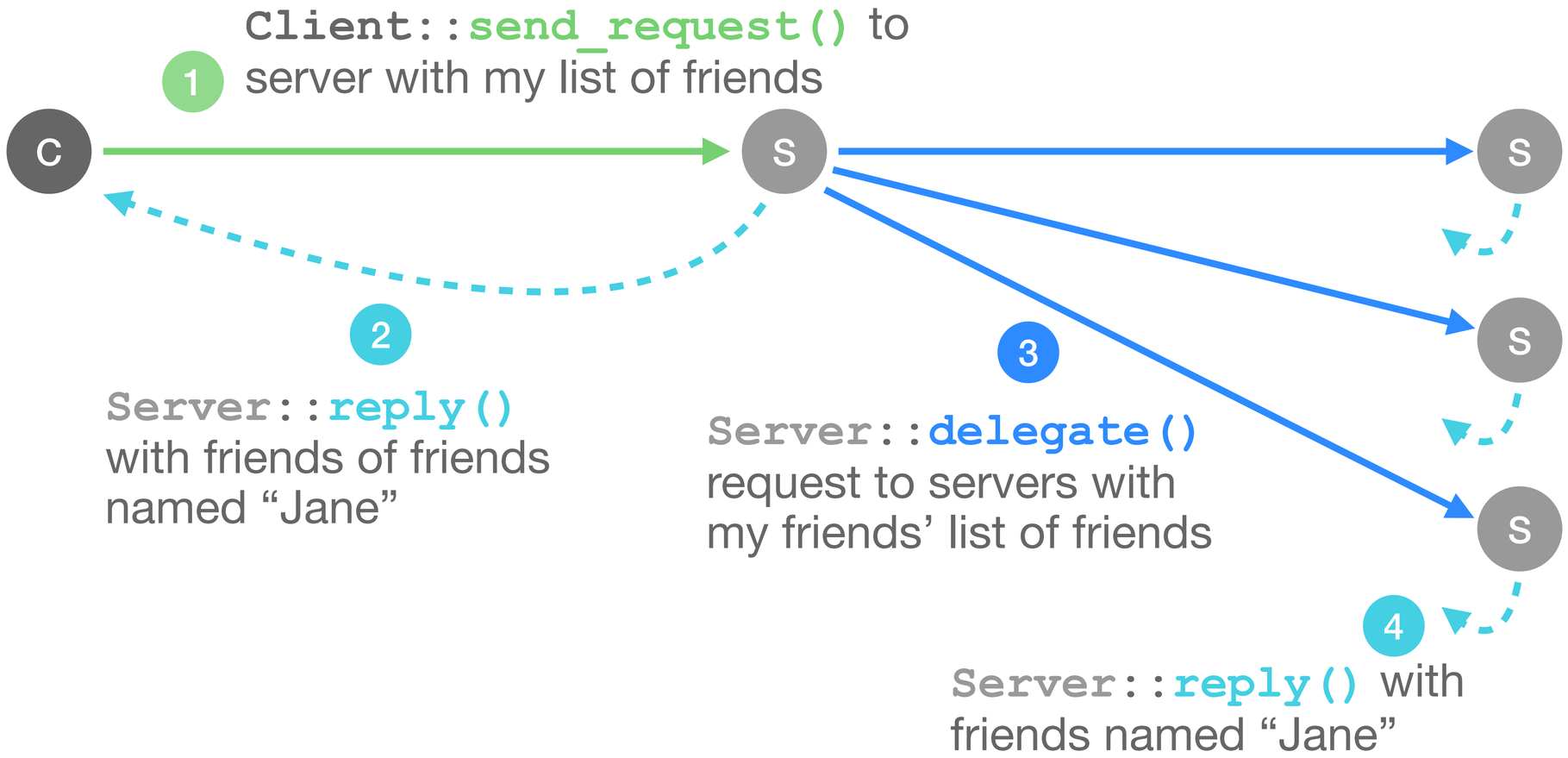
Send a **request** to another server

`reply()`

Return a **response** back to the client

Example: DPC in a Distributed Graph DB

Find all Friends and Friends of Friends named “Jane”



Implementing the Roo framework

A complete reference DPC framework implementation

- Designed for maximum application flexibility
  - Allows DPC communication pattern to be defined dynamically
  - Applications defined communication pattern during DPC execution
- Challenges for Roo implementation:
  1. Detecting when a DPC execution has **completed**
  2. Detecting when a DPC execution has **failed**

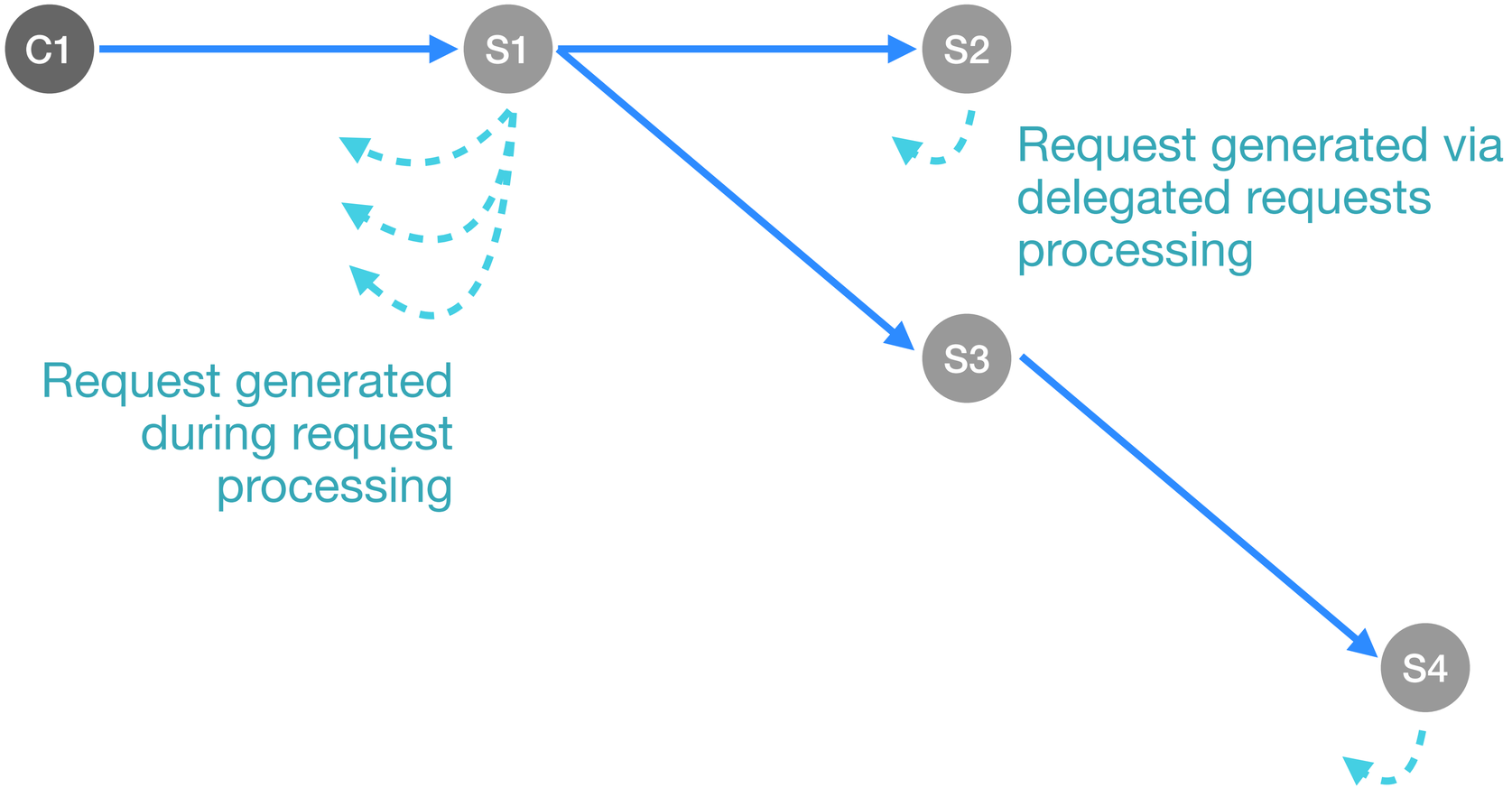
Detecting DPC Completion

Roo's implementation challenge

- DPC complete when all expected responses are received by the client
- **Challenge: How does the client know what responses to expect?**
  - Roo allows dynamic definition of communication pattern at run-time
  - No a priori knowledge of multi-hop structure
- Roo needs a dynamic way to build the expected response set

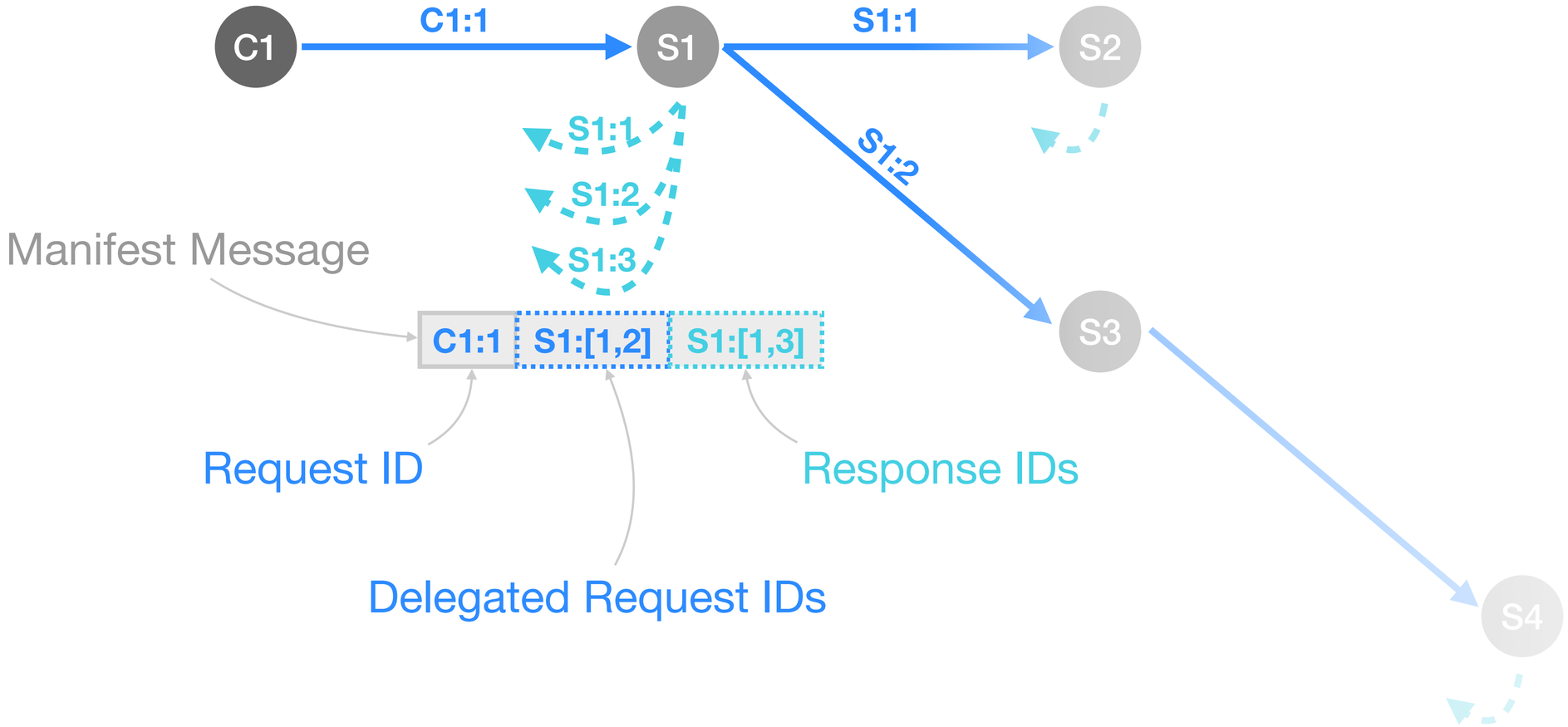
How responses are generated?

Dynamic DPC communication patterns



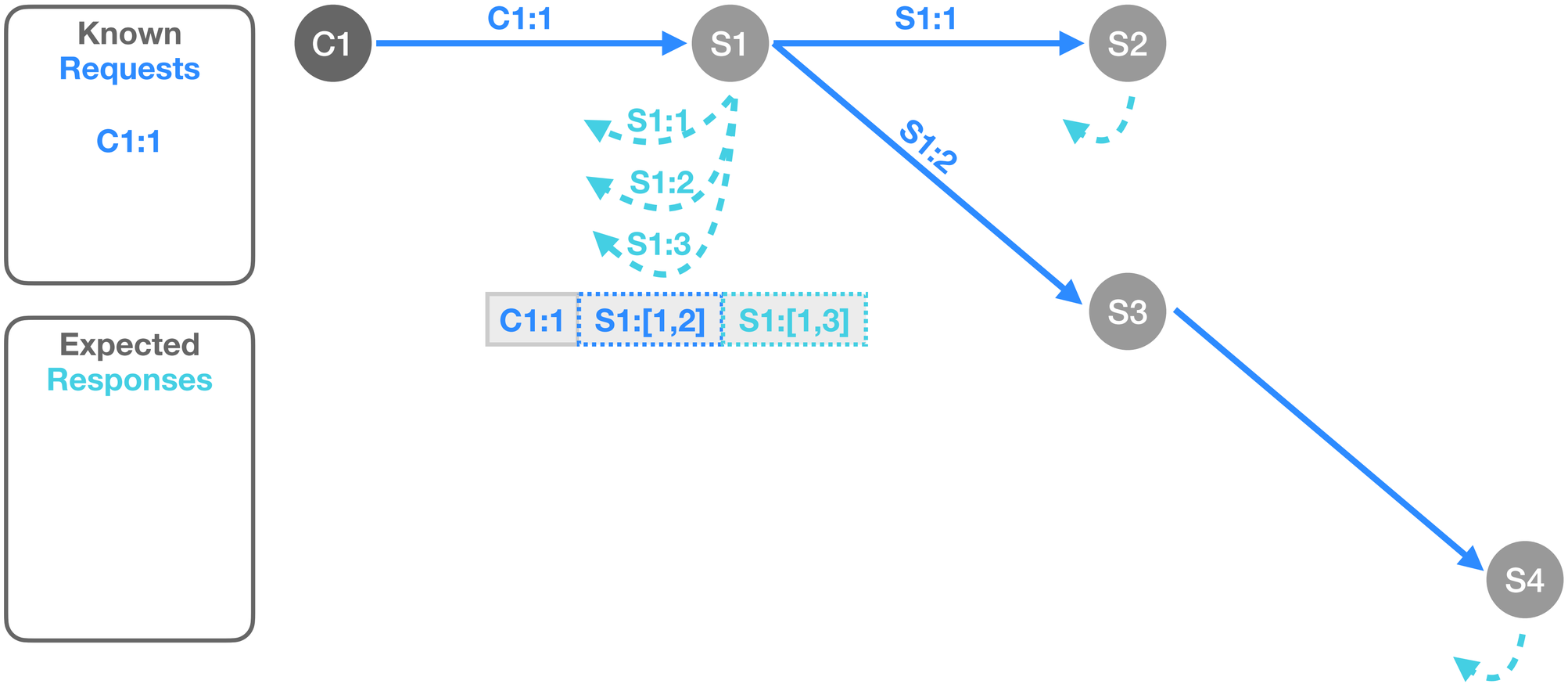
Manifest Messages

Collecting DPC metadata



Detecting DPC Completion with Manifests

How the Roo client uses manifests



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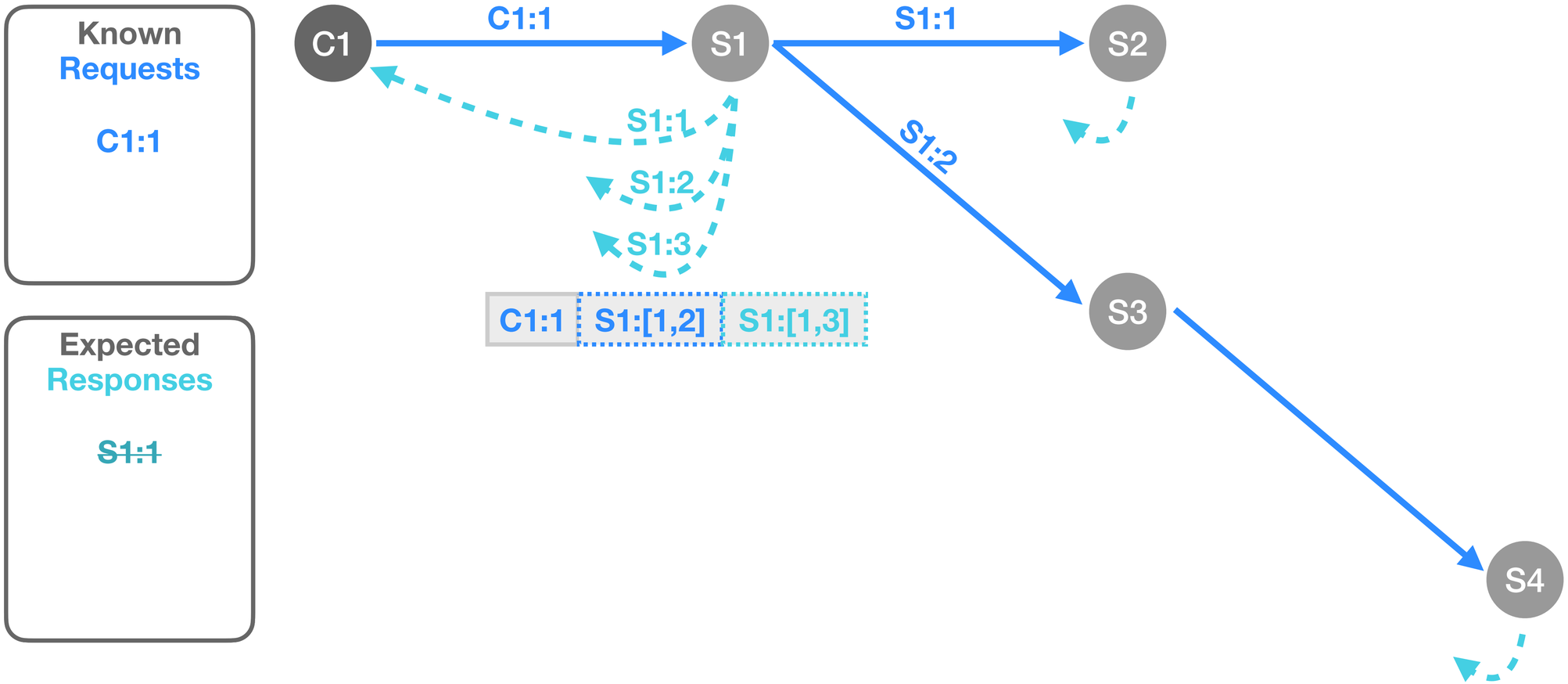

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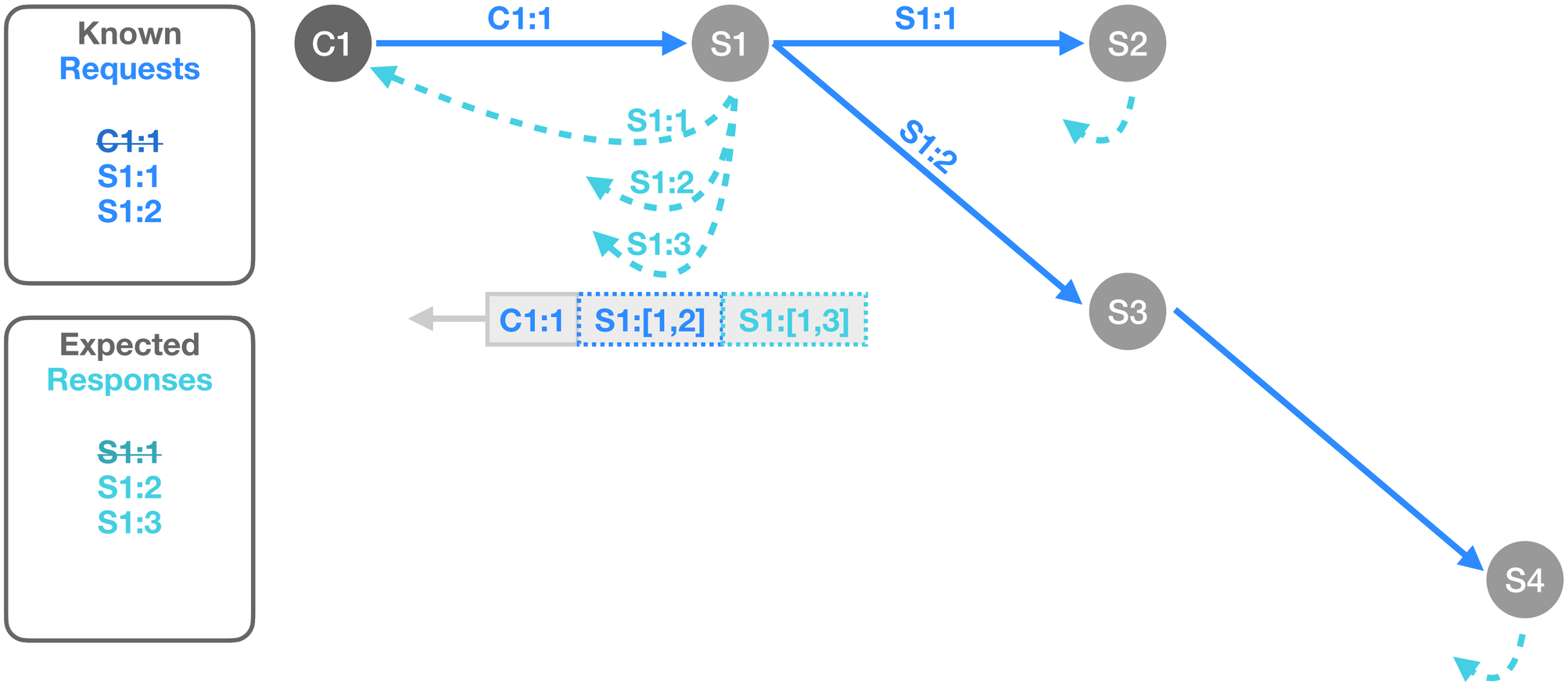

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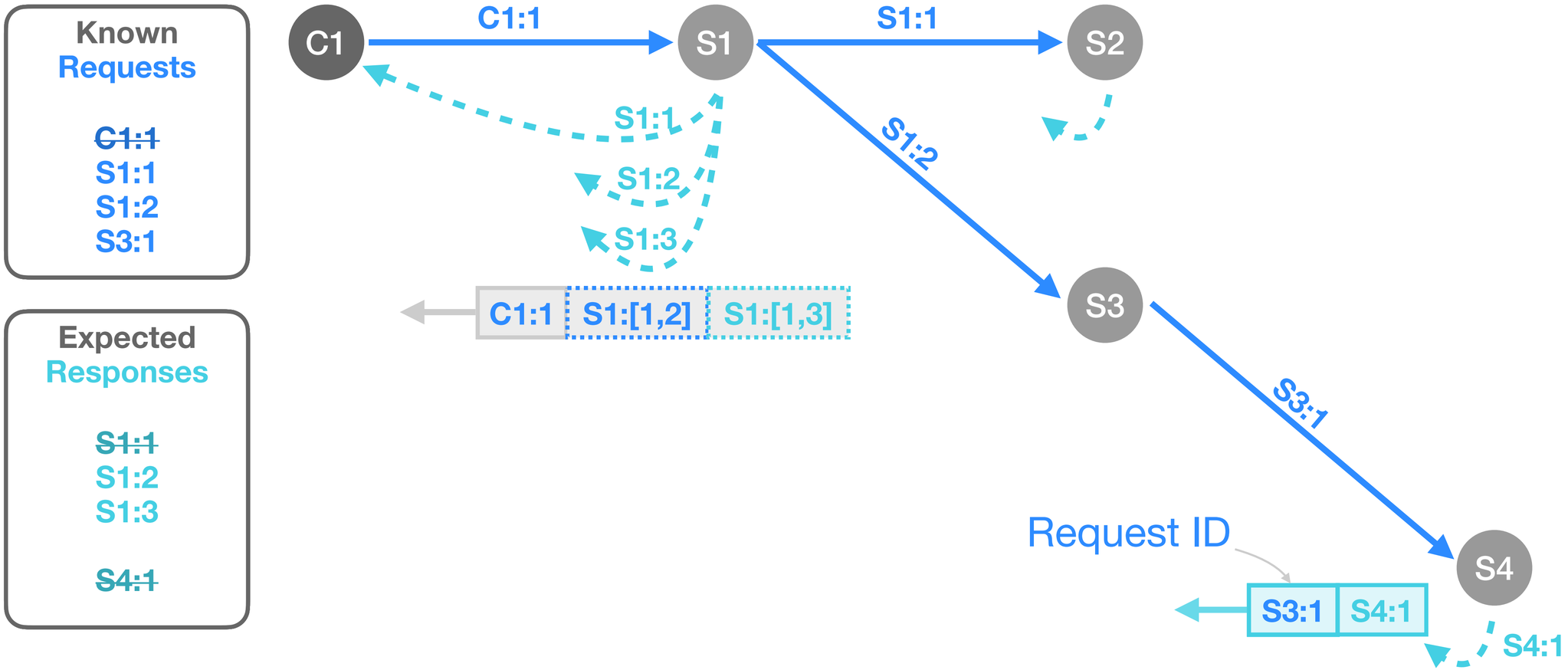

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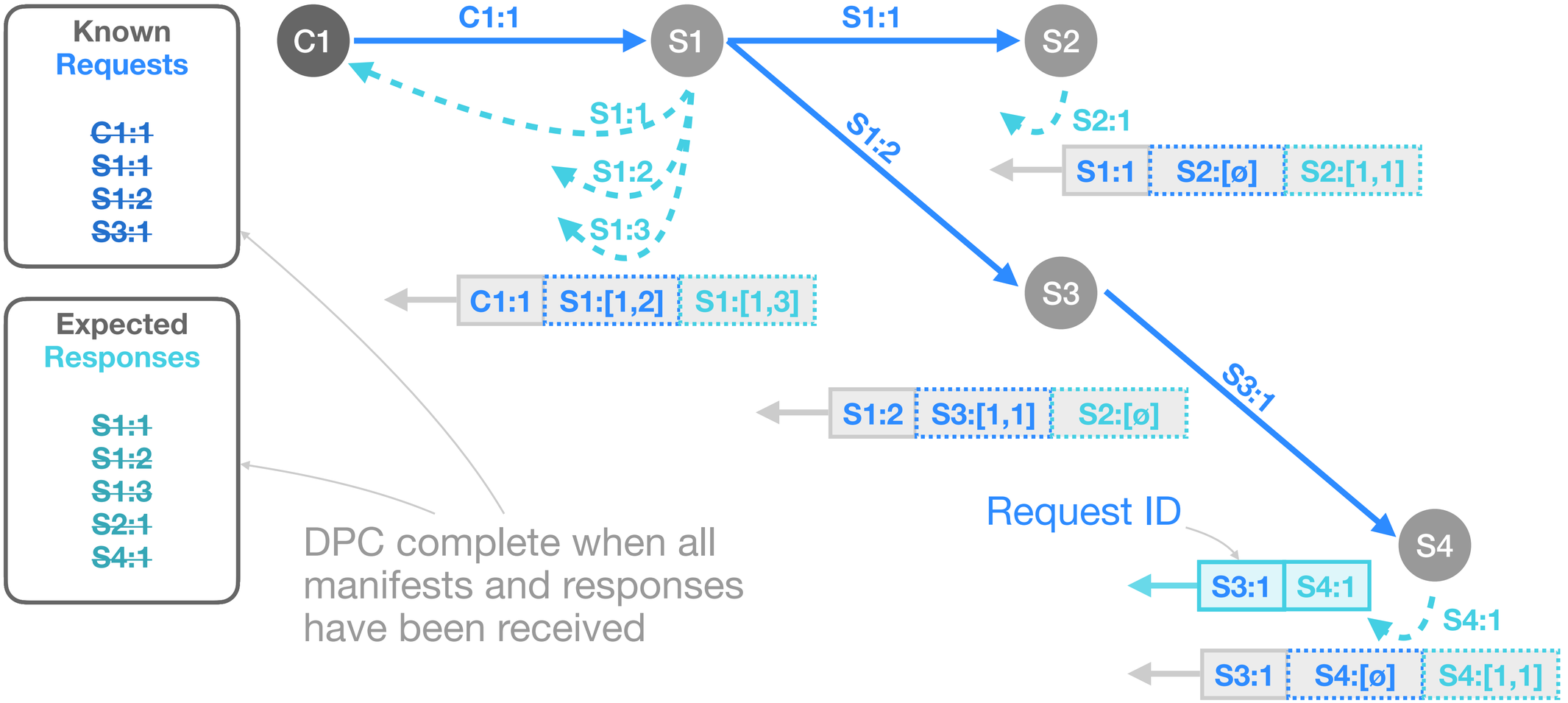
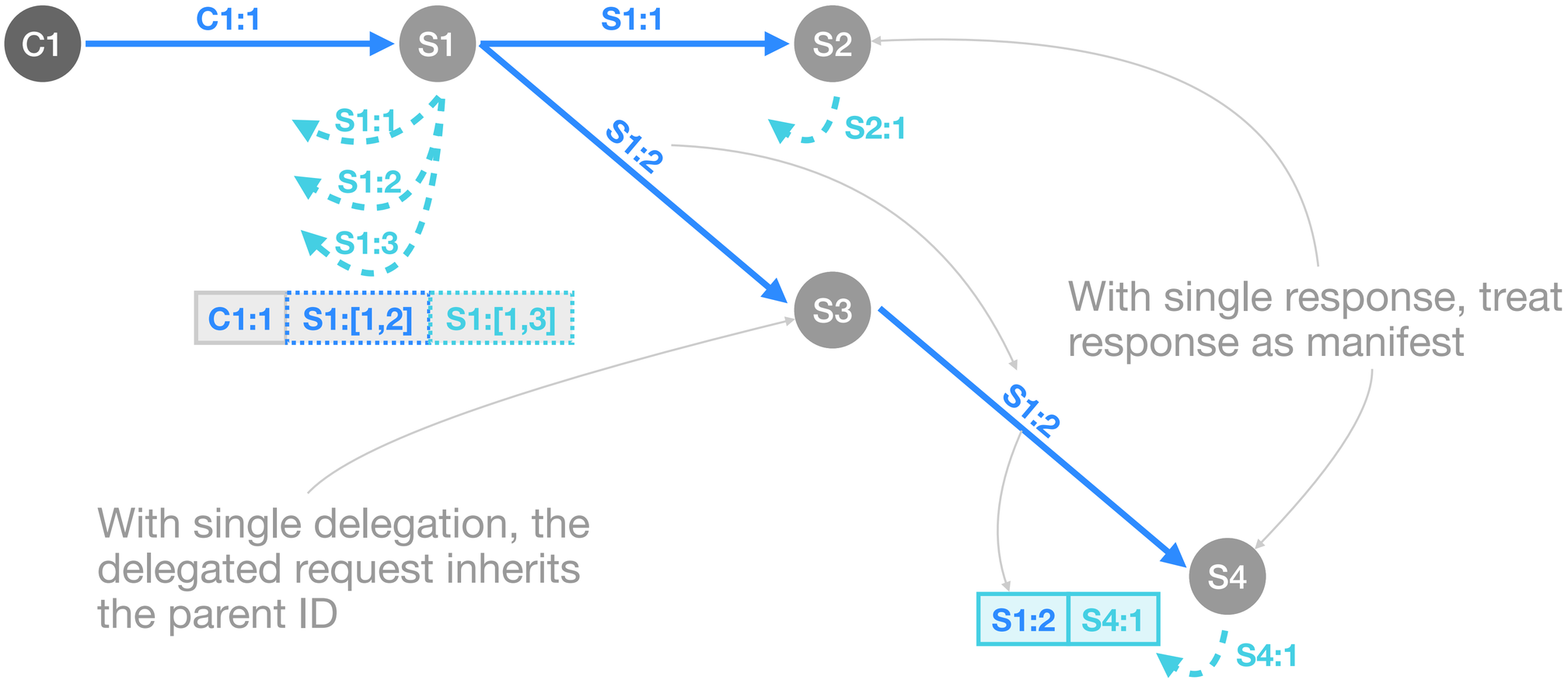


Optimizing Manifest Usage

Eliminate the need for manifests in the common case



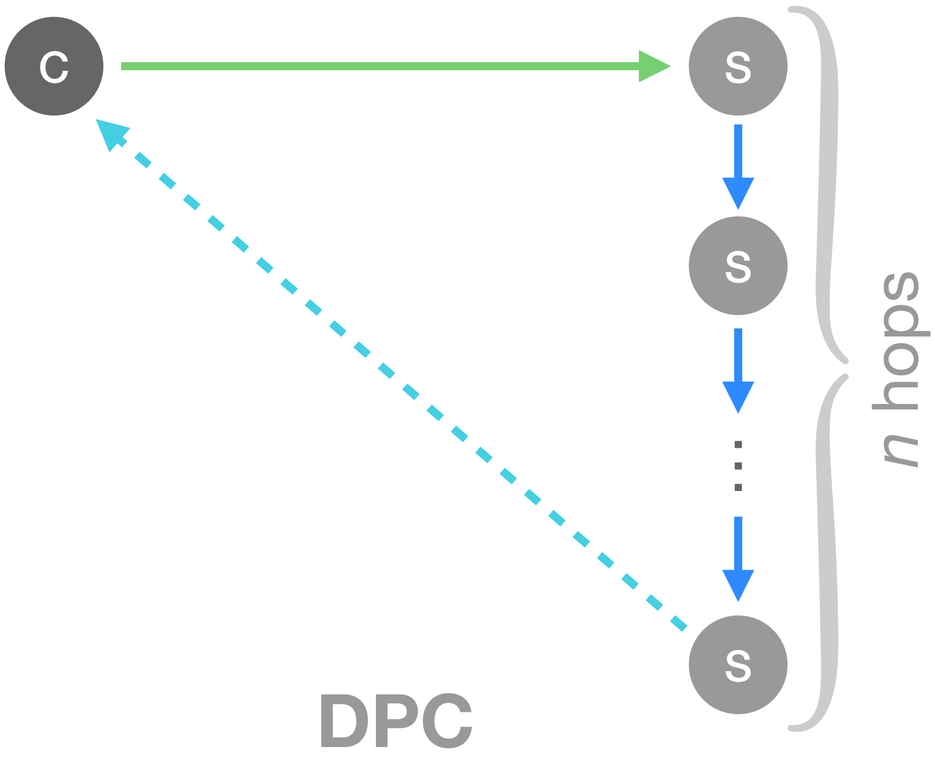
Evaluating DPC

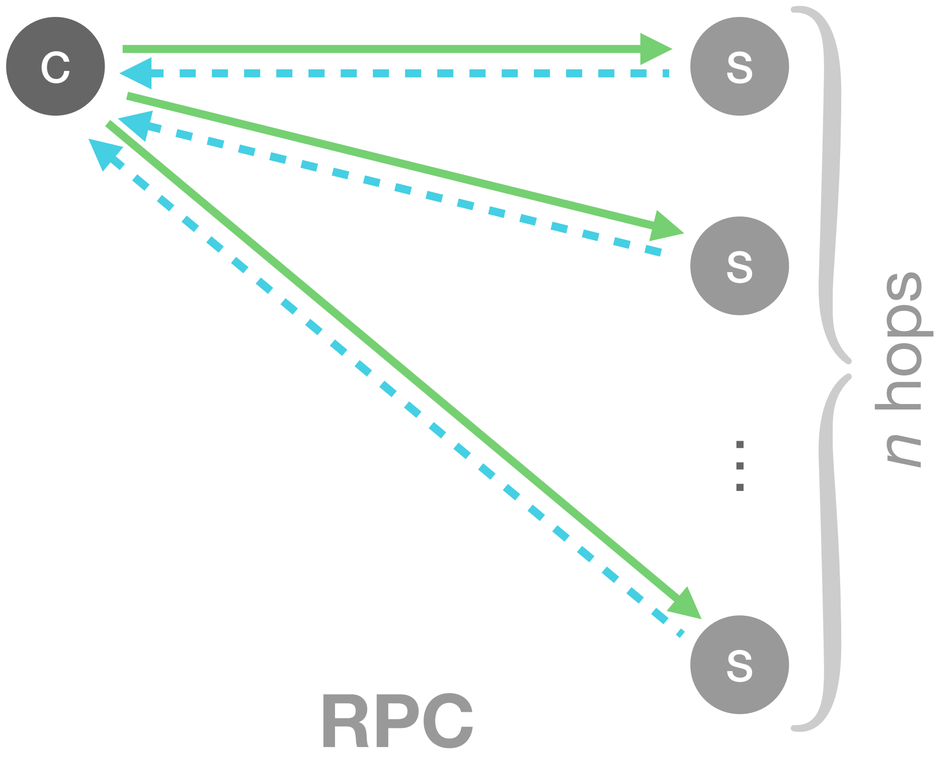
- DPC vs RPC Comparison
- Roo – implementation of DPC abstraction
  - C++ user-space library
  - Built with user-space implementation of Homa
  - Kernel-bypass with DPDK
- Comparable RPC framework
  - Shares mostly the same code as Roo
  - Optimized/simplified for RPC where possible
  - Allows for direct comparison of DPC vs RPC

- Hardware Setup (CloudLab xl170)
  - NIC: Two Dual-port Mellanox ConnectX-4 25Gbps NIC
  - Switch: 40Gbps HP FlexFabric 12910 switch
  - RTT: ~6us

Latency for various hop counts

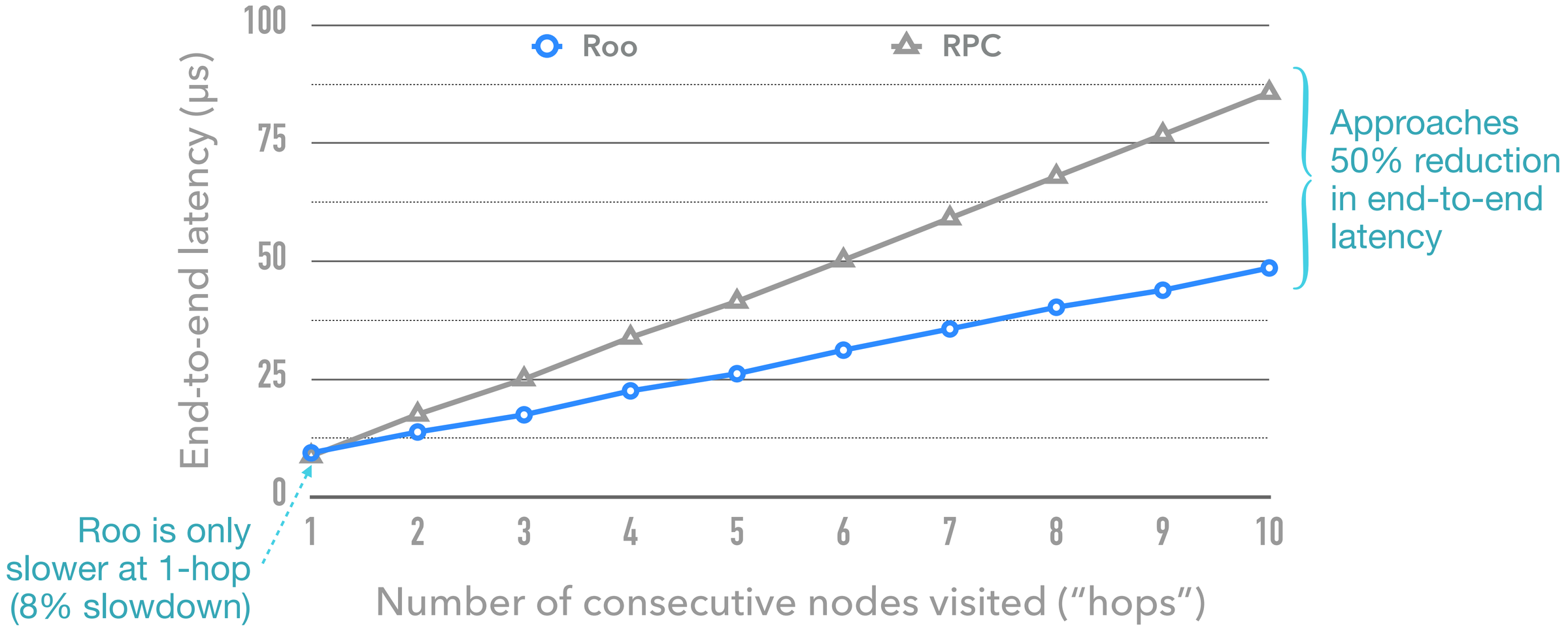
DPC vs RPC Benchmark Communication Pattern





Latency for various hop counts

Median latency for 100B message



Latency for various degrees of fan-out

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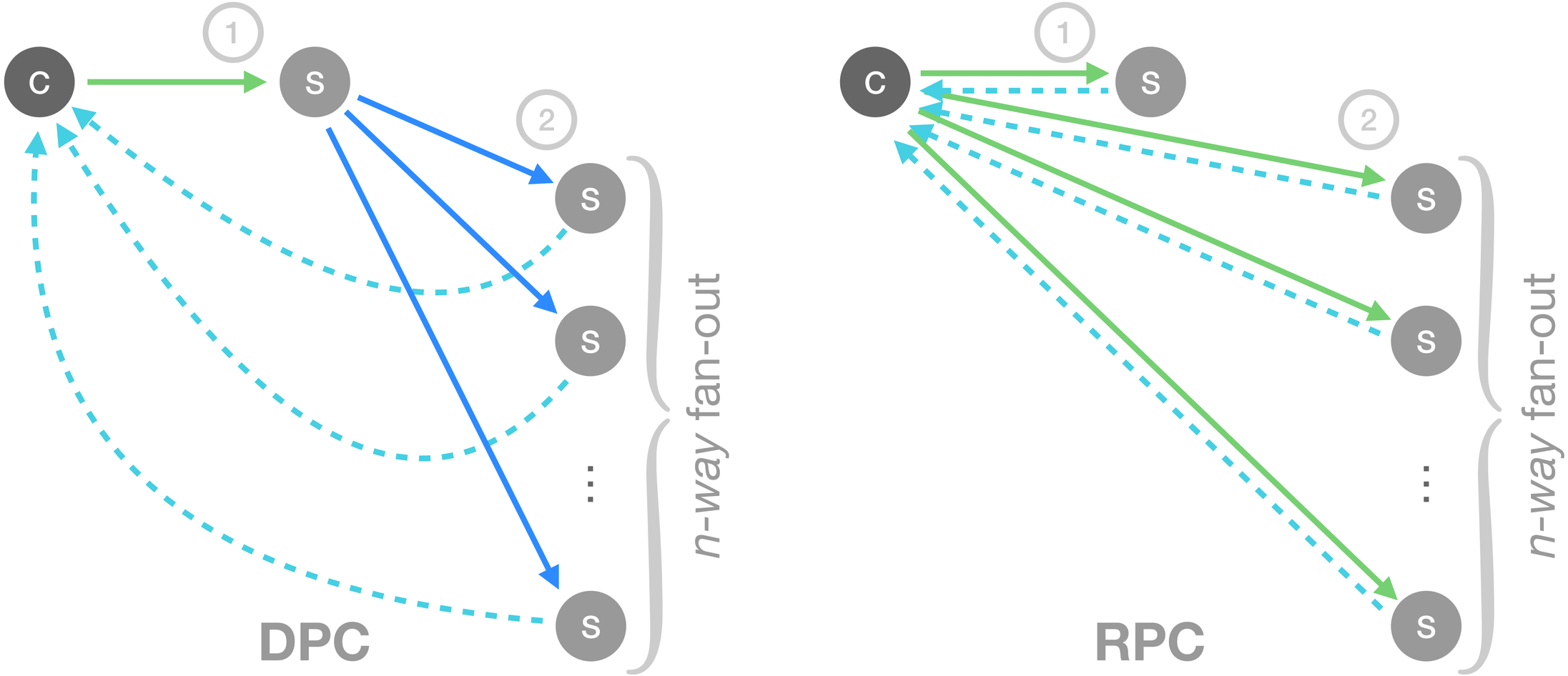

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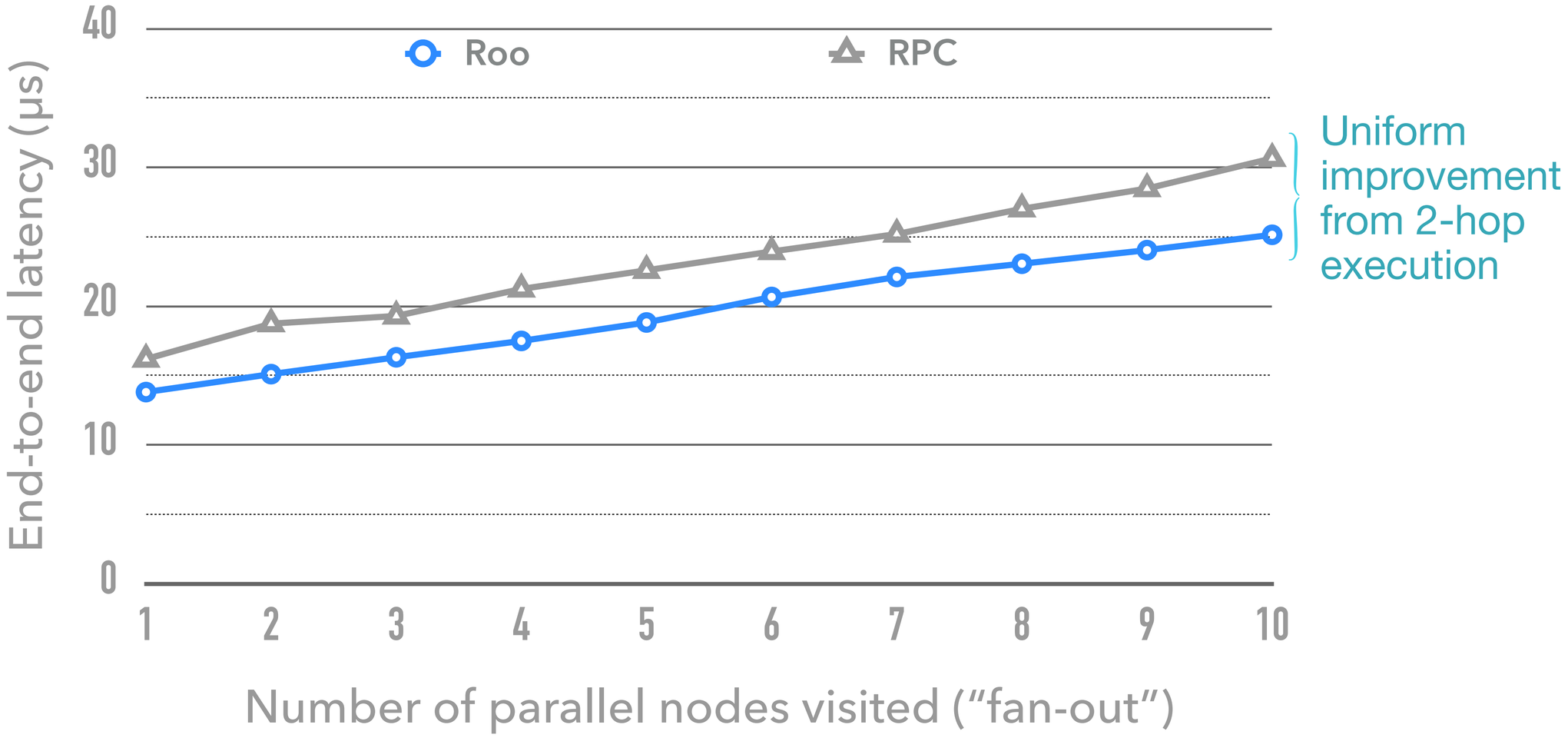
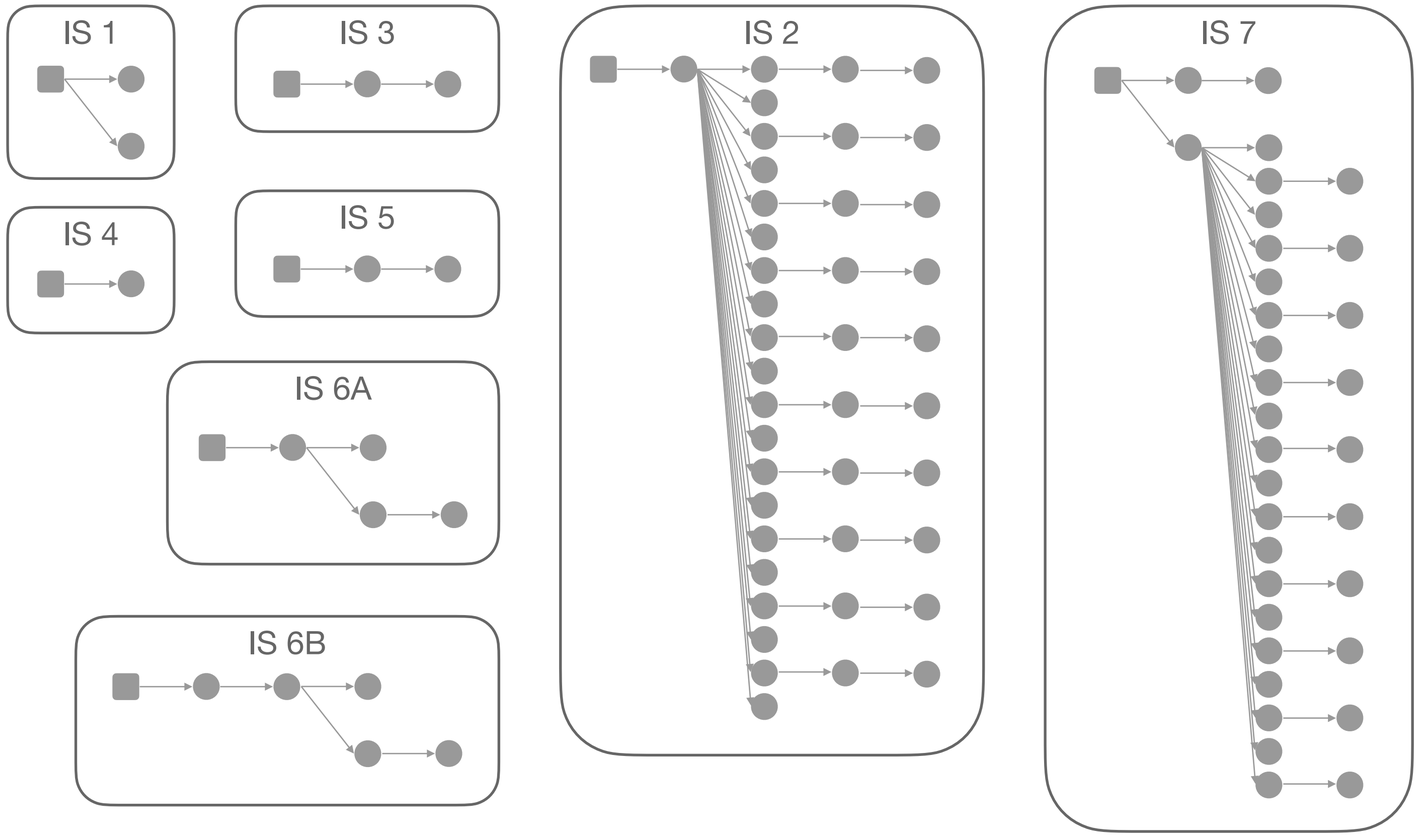


Graph DB Interactive Query Benchmark

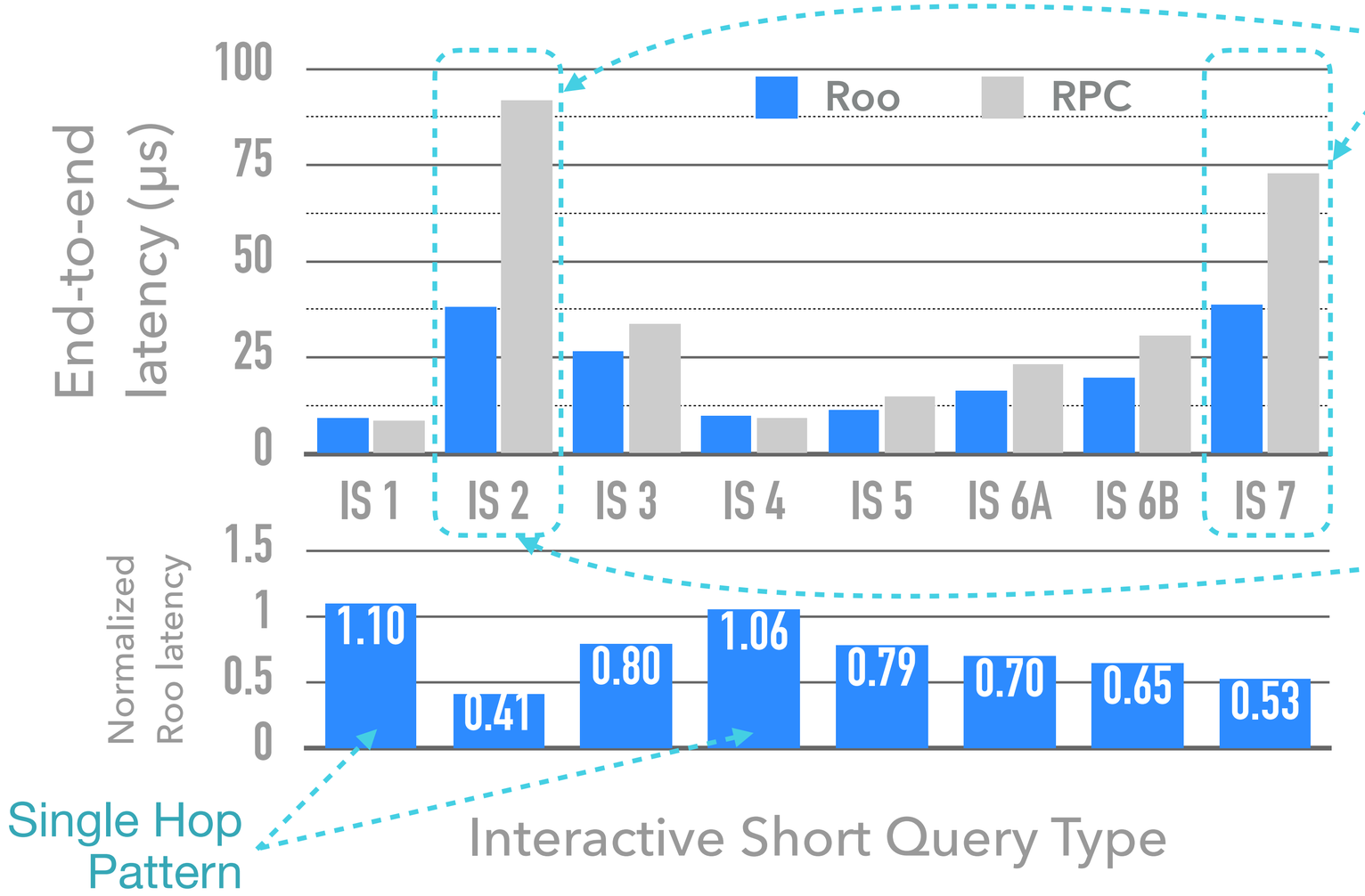
A set of "real-would" graph query patterns

- LDBC Social Network Benchmark
  - Industry standard graph database benchmark
  - Models graph representation of a social network application
- Interactive Short (IS) Queries
  - Common user interactions



Latency for Graph DB Interactive Queries

LDBC Social Network Benchmark Interactive Short (IS) Queries



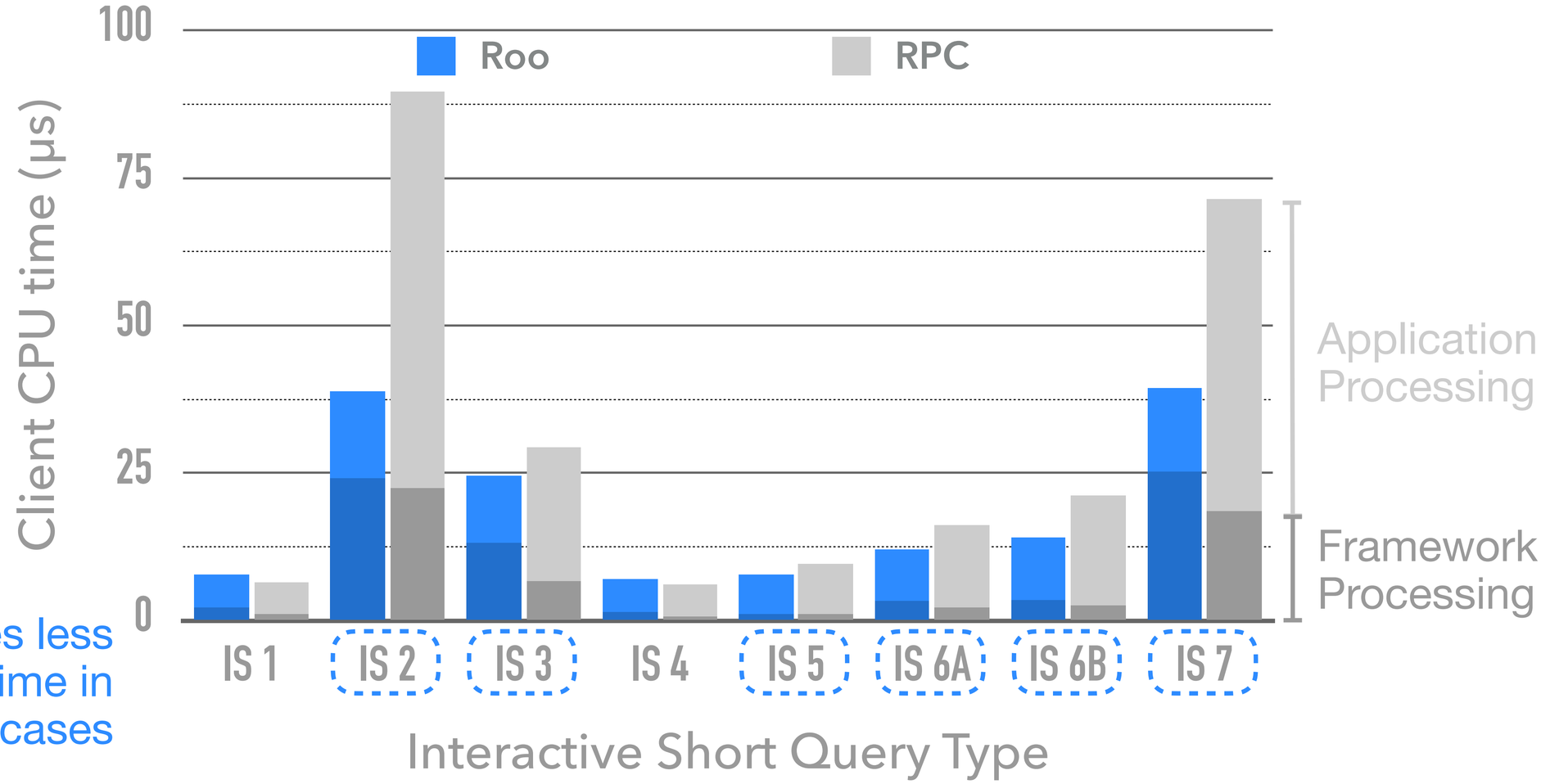
Greater reduction than predicted due to client bottleneck

Ex: 41 RPCs vs Roo with 21 messages

Single Hop Pattern

CPU time for Graph DB Interactive Queries

LDBC Social Network Benchmark Interactive Short (IS) Queries



Roo uses less total CPU time in multi-hop cases

Topics of Current and Future Work

Interesting issues that I didn't cover today

- Detecting DPC failure
- Reliability semantics
- Consistency semantics
- More applications and use cases
- DPC effect on throughput
- Optimizing metadata transmission
- Serialization and message structure

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PLATFORMLAB

Roo [https://github.com/**PlatformLab**/**Roo**]

Homa [https://github.com/**PlatformLab**/**Homa**]

Feedback? Use cases?

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