

Quantized Cache-to-Cache: Communication-Budgeted KV Transfer for Heterogeneous LLMs

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Abstract

We study communication-efficient transfer between heterogeneous large language models (LLMs) by quantizing Cache-to-Cache (C2C) KV-cache transfer. Our goal is to reduce bandwidth and memory while preserving accuracy. We present post-training quantization (INT8/INT4), cache-length reduction, and accuracy-versus-bytes curves for a heterogeneous model pair. Empirically, quantization is nearly lossless, while cache-length pruning reveals a strong front/back asymmetry that is critical for budgeted transfer. We release a reproducible evaluation pipeline and analysis scripts, and we outline a main-conference path toward sparse, projector-aware token selection and mixed precision.

1 Introduction

Large language models (LLMs) often communicate via text, which is slow and lossy. Cache-to-Cache (C2C) communicates via KV-cache projection and fusion, but does not address precision or bandwidth constraints. We ask: *How low can KV precision go before accuracy collapses, and can we recover performance under tight communication budgets?*

Contributions.

- We introduce a precision-aware C2C evaluation pipeline and quantify INT8/INT4 PTQ effects on C2C accuracy.
- We study cache-length reduction as a second budget axis and show that back-pruning consistently outperforms front-pruning.
- We report accuracy vs. communication-budget curves that jointly compare precision and cache length.
- We provide a reproducible benchmarking setup and analysis scripts to support extensions to QAT, mixed precision, heterogeneity, and selective transfer.

2 Background and Motivation

C2C projects sharer KV caches into receiver space and fuses them with learned gates, preserving rich semantics compared to text relay. However, KV caches are large: they scale with sequence length, KV heads, and head dimension. Quantization and cache-length reduction can shrink the communication footprint while retaining accuracy. This work reframes C2C through a communication-budget lens.

3 Related Work

C2C. Cache-to-Cache (C2C) enables direct semantic communication by projecting and fusing a sharer model’s KV cache into a receiver’s KV cache with learnable gates, avoiding intermediate text generation [1].

KV communication across agents. KVComm aligns KV caches across diverging prefixes using training-free offset correction with online anchors [2]. Q-KVComm adds adaptive layer-wise quantization, hybrid information extraction, and heterogeneous calibration for compressed KV transfer [3]. These works focus on multi-agent cache reuse/compression; our work studies quantization and cache-length pruning within the C2C projector+fuser pipeline.

Latent collaboration and cache alignment. KV cache alignment learns a shared latent space with adapters to align KV caches across models [4]. LatentMAS enables latent-space collaboration with shared working memory

without extra training [5]. Our approach stays within C2C’s KV fusion but emphasizes communication budgets and precision/length tradeoffs.

Token selection and KV compression. Token-level KV selection and value-norm importance improve long-context inference for a single model (ZipCache, TokenSelect, VATP) [6, 7, 8]. We adopt the budget perspective for C2C rather than single-model KV compression.

4 Method

4.1 C2C Recap

Let the sharer model produce KV caches (K_ℓ^S, V_ℓ^S) and the receiver produce (K_ℓ^R, V_ℓ^R) at layer ℓ . C2C projects sharer KV into receiver space via Π_ℓ^K, Π_ℓ^V and fuses them through a learnable gate:

$$(K_\ell^{R'}, V_\ell^{R'}) = \mathcal{F}_\ell(K_\ell^R, V_\ell^R, \Pi_\ell^K(K_\ell^S), \Pi_\ell^V(V_\ell^S)).$$

This avoids intermediate text and transfers richer internal semantics.

4.2 Post-Training Quantization (PTQ)

We quantize the KV caches using INT8 or INT4/NF4 with per-head scaling. We evaluate accuracy and latency under fixed precision budgets. Our current implementation uses fake-quant (quantize then dequantize) to model quantization noise without bit-packing.

4.3 Cache-Length Reduction

We prune KV tokens using a fixed ratio (e.g., 50%, 25%, 10%), reducing transmitted bytes further. We evaluate front-pruning and back-pruning to diagnose which instruction tokens are most valuable for cross-model transfer.

4.4 Selective and Compressed Cache Transfer (SparseC2C)

As a main-conference extension, we select a sparse subset of token positions to transfer and fuse. Let $I \subset \{1, \dots, T\}$ be selected tokens and S_I the gather operator. We fuse only selected tokens and scatter updates back:

$$\begin{aligned} (\tilde{K}_\ell^R, \tilde{V}_\ell^R) &= S_I^\top(K_\ell^R, V_\ell^R), \quad (\tilde{K}_\ell^S, \tilde{V}_\ell^S) = S_I^\top(K_\ell^S, V_\ell^S) \\ (\tilde{K}_\ell^{R'}, \tilde{V}_\ell^{R'}) &= \mathcal{F}_\ell(\tilde{K}_\ell^R, \tilde{V}_\ell^R, \Pi_\ell^K(\tilde{K}_\ell^S), \Pi_\ell^V(\tilde{V}_\ell^S)). \end{aligned}$$

We then scatter the update to the full cache. We use projector-aware token scoring by computing value norms in receiver space (“proj.vnorm.topk”), tying selection to the cross-model mapping.

4.5 Communication-Budget Curves

We report accuracy as a function of transmitted bytes, enabling fair comparison under equal communication constraints. For a sequence of length T , the approximate bytes are

$$\text{bytes} \approx T \cdot p \cdot 2 \cdot L \cdot H_{kv} \cdot d_h \cdot b/8,$$

where p is the retained cache proportion, L the number of layers, H_{kv} KV heads, d_h head dim, and b bits per element. We use this accounting for consistent budget curves.

5 Experiments

5.1 Setup

We evaluate on OpenBookQA and ARC-C with a Qwen3-0.6B receiver and Qwen2.5-0.5B sharer. We follow the C2C eval protocol: temperature 0, max_new_tokens 64, no CoT, unified chat template. All models are frozen; only the projector is trained when QAT is enabled. The OpenBookQA test split has 500 samples and ARC-C has 1150 samples.

5.2 Main Results

All results below are full runs. PTQ is effectively lossless relative to FP16, and cache pruning shows a strong front/back asymmetry.

Table 1: Baseline vs. PTQ (full-cache, %).

| Setting | OpenBookQA | ARC-C |
|---------------|------------|-------|
| FP16 baseline | 52.8 | 55.1 |
| INT8 PTQ | 52.8 | 55.0 |
| INT4 PTQ | 52.6 | 55.4 |

Table 2: OpenBookQA accuracy (% , 500 samples) for cache-length pruning (INT8).

| Order mode | 75% | 50% | 25% | 10% |
|------------|------|------|------|------|
| Front | 44.6 | 43.0 | 38.8 | 38.6 |
| Back | 52.2 | 52.0 | 50.8 | 49.2 |

Table 3: ARC-C accuracy (% , 1150 samples) for cache-length pruning (INT8).

| Order mode | 75% | 50% | 25% | 10% |
|------------|------|------|------|------|
| Front | 40.2 | 46.3 | 38.3 | 40.7 |
| Back | 55.7 | 57.2 | 56.2 | 53.7 |

5.3 Communication-Budget Curve

Figure 1 and Figure 2 report accuracy versus effective transmitted bytes. We plot the communication budget on a log scale when the dynamic range is large; each point is annotated with the retained cache proportion. These curves provide a single, comparable view across precision (FP16/INT8/INT4) and cache-length reduction.

5.4 Order-Mode Ablation

Across all cache lengths, **back-pruning** (keeping later instruction tokens) consistently outperforms **front-pruning**. At 50% cache length, for example, back-pruning retains near-baseline accuracy while front-pruning degrades sharply. This suggests late instruction tokens carry higher utility for cross-model KV fusion, a useful design signal for future selective transfer methods.

5.5 Main-Conference Extensions (Preliminary)

We report early results for two main-conference extensions. Mixed precision (INT8 with FP16 in the last layers) remains near baseline. An alignment-only ablation (same model pair, alignment enabled) reduces accuracy, suggesting alignment should be reserved for heterogeneous pairs. For SparseC2C (token selection), the $p=1.0$ run matches baseline; $p=0.5$ yields 50.2 on OpenBookQA with ARC-C pending. Full grids will be reported in the main-conference track.

6 Discussion

Quantized C2C provides large bandwidth reductions with limited accuracy drop. Cache pruning further improves the tradeoff, suggesting a practical path to deployable multi-LLM communication. A main-conference path includes QAT recovery, mixed-precision schedules, heterogeneous model pairs, and SparseC2C token selection.

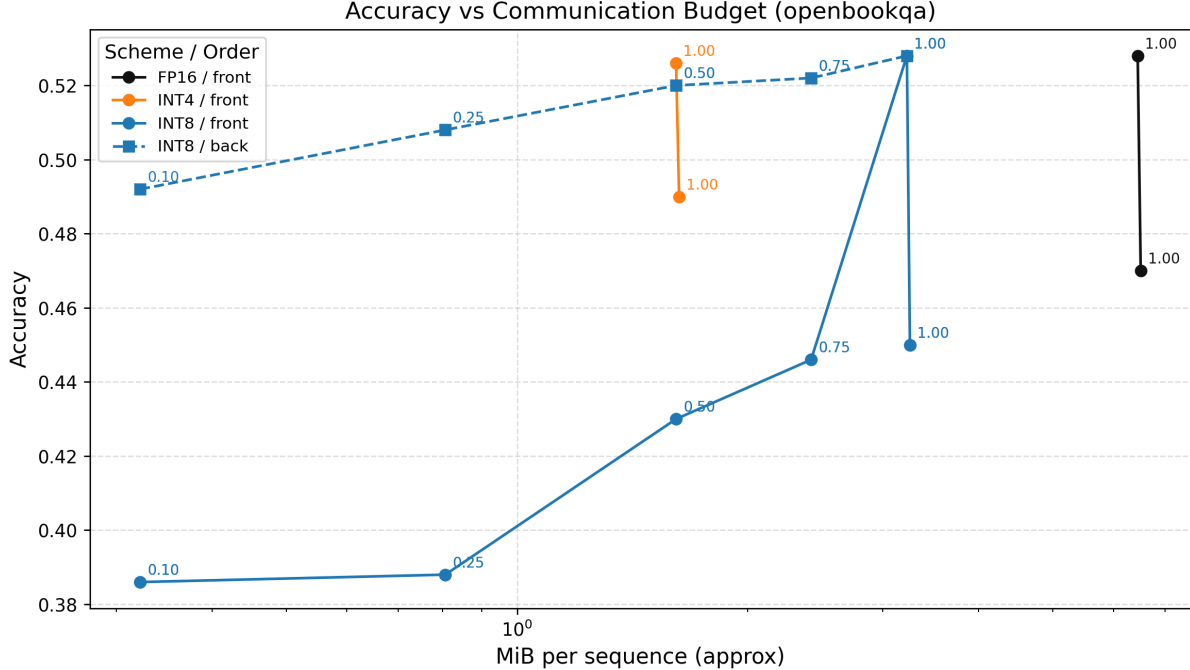


Figure 1: Accuracy vs. communication budget (OpenBookQA).

Table 4: Preliminary extension results (% accuracy).

| Setting | OpenBookQA | ARC-C |
|--------------------------------------|------------|-------|
| Mixed precision (INT8 + last-4 FP16) | 52.8 | 55.0 |
| Alignment ablation (same pair) | 46.8 | 49.6 |

7 Limitations

Our results currently focus on a single model pair and two datasets. We do not yet report end-to-end latency or FLOP measurements for the fuser, and SparseC2C remains an ongoing extension. These limitations will be addressed in the main-conference track.

8 Broader Impacts

Communication-efficient multi-LLM systems can reduce compute and latency, but they may also enable higher-throughput deployment of models. We emphasize reproducible evaluation, careful reporting of accuracy/latency trade-offs, and responsible deployment in sensitive domains.

9 Conclusion

We introduce precision-aware C2C and report accuracy vs. bytes curves. This establishes a communication-budget perspective for cross-model KV transfer and opens the door to low-latency, low-bandwidth agent collaboration.

Acknowledgments

Placeholder.

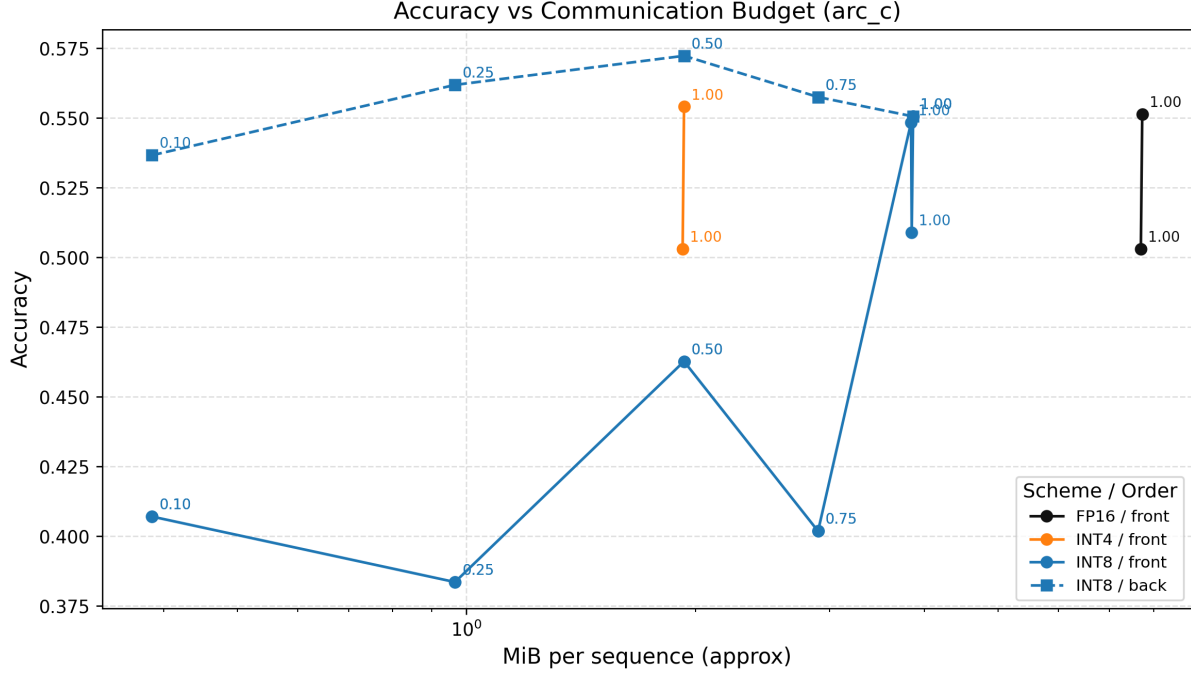


Figure 2: Accuracy vs. communication budget (ARC-C).

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