

Figure 5: Coordination Bounds - Theory and Validation

ALGEBRAIC

ADD, MAX, MIN, UNION

Theory: $C = 0$

Proven: Commutative ops
need no coordination

VALIDATED

GENERIC

OVERWRITE, CAS

Theory: $C = \Omega(\log N)$

Proven: Non-commutative
requires consensus

ENFORCED

EMPIRICAL VALIDATION

Phase 1: $32,114\times$ speedup measured (single-node)

Phase 2: OVERWRITE rejected with "requires coordination"

Conclusion: System correctly enforces algebraic boundary