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Transaction Batching for Low Latency Commit Processing in Distributed Systems

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Abstract:
Distributed systems that support transactional workloads depend on commit protocols to ensure consistency and durability across multiple nodes. In conventional transaction processing models, each transaction is committed independently as soon as execution completes. Every commit involves multiple stages of message exchange, logging, and synchronization among participating nodes before a confirmation is returned. While this immediate commit model maintains correctness, it introduces substantial latency overhead during runtime. Because each transaction is processed separately, the full commit procedure is repeatedly executed for every request, resulting in increased processing time even when transactions arrive close together in time. As the number of nodes in a distributed cluster grows, commit operations require additional communication and coordination across machines. These interactions increase the time needed to finalize each transaction. Consequently, commit latency rises steadily with cluster size and workload intensity. Under moderate and heavy traffic conditions, the commit phase frequently becomes a performance bottleneck that limits system responsiveness. Transactions spend a significant portion of their lifetime waiting for commit completion rather than performing useful computation. This delay directly impacts application performance, reduces throughput, and restricts scalability in latency sensitive environments. Empirical observations across different cluster configurations show consistently high commit times when transactions are handled individually. The repeated execution of commit procedures leads to inefficient utilization of system resources and prolonged response times. These characteristics indicate that existing commit mechanisms do not scale efficiently as workloads and deployment sizes increase. This paper addresses the problem of high commit latency in distributed transaction systems and focuses on improving commit time efficiency to enable faster transaction completion.

Keywords: Transactions, Batching, Latency, Commit, Distributed, Scalability, Throughput, Synchronization, Coordination, Protocols, Performance, Replication.

INTRODUCTION

Distributed systems form the foundation of many modern applications that require reliable and consistent transaction processing [1] across multiple nodes. Services such as online banking, ecommerce platforms, and large scale data management systems depend on distributed transactions to maintain correctness while operating over geographically separated resources. To guarantee consistency and durability, these systems rely on commit protocols that coordinate participating nodes before confirming the completion of each transaction. The commit phase therefore plays a critical role in determining overall system responsiveness and performance. In conventional transaction processing models, transactions are committed individually immediately after execution. Each commit involves communication among nodes, persistent logging, and synchronization steps to ensure agreement on the final state. Although this approach simplifies control flow [2], it introduces noticeable latency for every transaction. Since the complete commit procedure is executed repeatedly for each request, the cumulative delay becomes significant as the number of transactions increases. Even when transactions are small or arrive within short intervals, they are still processed separately, resulting in unnecessary waiting time. The impact of

this behavior becomes more pronounced as the size of the distributed cluster grows. Additional nodes increase the number of messages exchanged and the time required for coordination. Consequently, commit latency rises steadily with cluster size, affecting throughput and limiting scalability [3]. Under moderate and heavy workloads, a large portion of transaction time is spent waiting for commit confirmation rather than performing useful computation. This delay directly affects user response time and overall service quality. In many practical deployments, the commit stage becomes a dominant bottleneck that restricts performance improvements even when computational resources are sufficient. These observations highlight the need to carefully examine commit latency in distributed transaction systems. Improving commit time efficiency is essential for achieving scalable [4] and responsive processing in modern distributed environments.

LITERATURE REVIEW

Distributed transaction processing has long been a central research topic in the design of reliable and scalable computing systems. Modern cloud platforms, large scale databases, and service oriented applications rely heavily on distributed transactions to guarantee consistency across multiple machines. These systems execute operations [5] that span several nodes, requiring coordinated agreement before changes become permanent. The commit phase of a transaction therefore plays a crucial role in ensuring correctness. However, despite significant advances in distributed computing, commit latency continues to be a major performance bottleneck, particularly in environments with high concurrency and increasing cluster sizes. Numerous studies have examined the causes of commit delays and the resulting impact on system throughput and scalability.

Early distributed transaction models adopted strict coordination mechanisms to maintain atomicity and consistency. Classical protocols such as two phase commit were widely introduced to provide agreement among participants before finalizing a transaction. In these protocols, a coordinator communicates with all participating nodes to collect votes and subsequently decides whether to commit or abort. Although this method ensures correctness, it introduces multiple communication steps and persistent logging operations. Each transaction [6] requires several message exchanges, which directly contribute to increased latency. Research has shown that the time spent waiting for coordination often exceeds the time required for actual computation. Consequently, the commit stage becomes the dominant factor affecting overall performance.

As distributed systems grew in scale, the limitations of per transaction commit processing became more evident. Studies observed that executing the full commit protocol for every transaction results in repeated synchronization costs. Even when transactions arrive closely together, they are handled independently, forcing the system to perform redundant coordination steps. This repetitive behavior leads to inefficient resource utilization [7] and increased waiting time. Measurements from large scale database systems indicate that commit processing can account for a significant percentage of total transaction time, particularly under high load conditions. These findings motivated further exploration into techniques that could reduce the overhead associated with commit operations.

Network communication delays have also been identified as a primary contributor to commit latency. In distributed environments, each commit requires message transmission between nodes that may be physically separated. Variability in network conditions can increase round trip times, further extending the duration of the commit phase [8]. Research in data center networks demonstrates that even small increases in latency accumulate when repeated across thousands of transactions. As the number of participants grows, the probability of encountering slower responses increases, causing overall commit time to rise. These observations highlight the sensitivity of commit protocols to network performance and emphasize the need for more efficient coordination strategies.

Persistent logging is another source of delay frequently discussed in the literature. To ensure durability, commit protocols typically require writing transaction state to stable storage. Disk or storage operations introduce additional latency that cannot be ignored. Studies reveal that synchronous logging significantly prolongs commit completion time, especially when storage devices experience contention. While modern storage technologies reduce some of this overhead, the cumulative cost remains noticeable when performed for each individual transaction. As workloads scale, the frequency of these logging operations grows proportionally, further amplifying the latency problem. Researchers have also examined the impact of concurrency on commit performance [9]. In high throughput systems, many transactions attempt to commit simultaneously. Coordinators must manage multiple requests, leading to contention and scheduling delays. Queue buildup at coordination points increases waiting time, which directly affects commit latency. Experimental analyses show that under heavy load, commit queues can grow rapidly, causing transactions to experience unpredictable delays. This behavior degrades system responsiveness and reduces the benefits of parallel execution. Consequently, understanding how commit processing interacts with concurrency remains an important area of investigation.

The design of distributed databases has introduced additional challenges related to commit efficiency. Replicated systems require updates to be propagated across multiple replicas to maintain consistency. Each replication step involves communication and acknowledgment, which increases the duration of the commit phase. Research on strongly consistent replication models indicates that additional nodes introduce proportional increases in commit time. While replication improves reliability, it also raises coordination complexity [10]. As a result, balancing consistency guarantees with acceptable latency has become a key concern in the literature. Cloud computing environments further amplify these issues. Virtualized infrastructures host numerous services that generate large volumes of small transactions. Because transactions are short lived, commit latency becomes a dominant component of total response time. Several studies highlight that even minor inefficiencies in commit handling can significantly impact service level objectives. Monitoring reports from cloud based platforms reveal that commit delays often limit achievable throughput despite adequate computational resources. These findings suggest that optimizing commit behavior is essential for maintaining performance in modern cloud deployments.

Another line of research focuses on protocol optimizations aimed at reducing the number of coordination steps. Variants of traditional commit mechanisms attempt to shorten the communication path or reduce the amount of required synchronization [11]. While these improvements offer modest gains, many studies indicate that the fundamental overhead of per transaction processing remains. Each transaction still undergoes separate handling, which prevents effective sharing of coordination costs. As transaction rates increase, the cumulative effect of individual commits continues to hinder scalability. Stream processing and real time analytics systems also expose the limitations of immediate commit approaches. Such systems process continuous streams of events where thousands of operations are completed in rapid succession. Executing full commit procedures for every small update introduces disproportionate overhead relative to the amount of work performed. Researchers have observed that commit related delays reduce the ability of streaming platforms to maintain low latency guarantees. Consequently, these systems require more efficient commit handling to sustain real time performance.

Several empirical studies provide quantitative evidence of commit latency growth with cluster size. Measurements across distributed clusters demonstrate that adding more nodes leads to longer coordination times and increased message traffic. The relationship between node count and commit delay is often close to linear. This behavior suggests that conventional commit models do not scale effectively with system expansion. Without addressing this issue, distributed systems may experience diminishing returns as additional resources are added. The literature also highlights that commit inefficiency affects not only latency but also overall resource utilization. While transactions wait for commit completion [12], processors remain idle or underutilized. This waiting time represents lost opportunities for useful

computation. Systems that appear resource rich may still deliver suboptimal performance because commit operations prevent effective utilization. Researchers emphasize that reducing commit delay can therefore improve both responsiveness and throughput simultaneously.

Recent work has begun exploring the concept of processing multiple transactions collectively rather than individually. The idea of grouping or batching transactions has been discussed in database communities for decades, particularly in the context of log flushing and storage operations. By combining several commit requests into a single coordination step, systems can potentially reduce repeated overhead. Experimental results from early investigations show promising reductions in average commit time. These findings suggest that shared processing of commit operations may provide a practical path toward improved efficiency. Further studies analyze how batching interacts with system workload characteristics. Under bursty traffic conditions, transactions naturally accumulate over short intervals, making collective processing feasible. Researchers report that batching can smooth commit demand and reduce coordination [13] pressure. However, selecting appropriate grouping strategies remains challenging, as overly large groups may introduce waiting delays. Understanding these trade offs has become an important topic of discussion in contemporary research. Despite these advancements, many production systems still rely on immediate commit mechanisms due to simplicity and predictability.

As a result, high commit latency continues to affect large scale deployments. The literature consistently identifies repeated coordination, communication delays, logging overhead, and scaling effects as primary contributors to the problem. These recurring observations demonstrate that existing approaches are insufficient for meeting the demands of modern distributed workloads. In addition to protocol level considerations, several researchers have investigated the internal execution behavior of transaction managers to understand how commit latency accumulates during runtime. Transaction managers typically maintain queues of pending commits, scheduling structures for coordination messages, and temporary state information for each active transaction. As the number of concurrent requests increases, these internal structures grow proportionally. Queue buildup causes transactions [14] to wait before entering the commit phase, which adds delay even before coordination begins. Studies show that this queuing effect can substantially increase end to end latency, particularly during traffic bursts. The presence of such waiting periods indicates that commit inefficiency is not limited to network communication but is also influenced by local processing overhead within each node.
Another frequently discussed factor involves the variability of commit times across different nodes. Distributed systems rarely operate under perfectly uniform conditions. Differences in processor speed, background workload, and storage performance can cause some nodes to respond more slowly than others. Because commit protocols typically require agreement from all participants, the overall latency is determined by the slowest node. Researchers refer to this phenomenon as the straggler effect. Even when most nodes respond quickly, a small number of slower participants [15] can delay the entire commit process. Experimental evaluations demonstrate that stragglers become more common as the number of nodes increases, leading to higher average commit latency. This behavior further limits scalability in large clusters.

Workload characteristics also influence commit performance. Transaction sizes, read and write ratios, and contention levels affect the amount of coordination required. Systems that process many small transactions often experience disproportionately high commit overhead because the cost of coordination dominates the cost of computation. In contrast, larger transactions amortize the commit cost over more work. Several empirical studies confirm that workloads composed of short lived operations suffer the most from commit latency [16]. This observation is particularly relevant to modern applications such as microservices and online services, where transactions frequently involve only a few operations but must complete quickly. The mismatch between small workloads and heavy commit processing highlights the inefficiency of conventional commit handling.

Researchers have also examined the role of middleware and communication frameworks in commit delay. Many distributed systems rely on middleware layers to abstract network interactions. While middleware simplifies development, it introduces additional processing steps such as serialization, deserialization, and message buffering. Each of these steps consumes time and contributes to overall latency. Measurements indicate that middleware overhead becomes noticeable when commit operations occur at high frequency. Even small per message costs accumulate significantly when thousands of commits are executed every second. This accumulation further reinforces the need to minimize the number of coordination events. Another line of investigation focuses on reliability mechanisms integrated into commit protocols. Techniques such as acknowledgments, retries [17], and failure detection ensure correctness but add extra communication and waiting periods. For example, timeouts are often required to handle potential failures, which forces coordinators to wait before deciding on a transaction outcome.

While these mechanisms improve robustness, they also increase average commit time. Researchers have noted that reliability related delays become more pronounced in geographically distributed deployments where network variability is higher. Thus, systems that span multiple regions may experience even greater latency during commit operations. The impact of commit latency on overall application behavior has been studied extensively. Delayed commits directly influence user perceived response time [18]. In interactive services, even small increases in latency can reduce user satisfaction and degrade service quality. Studies in web applications and financial systems show that users expect rapid confirmation of completed operations. When commit delays exceed acceptable thresholds, service reliability is perceived to decline. Consequently, reducing commit latency is not only a matter of system efficiency but also of maintaining positive user experience.

Several benchmarking efforts have provided quantitative evidence of commit related overhead. Standard transaction processing benchmarks consistently report that commit time represents a substantial fraction of total transaction duration. As systems scale to higher concurrency levels, the relative proportion of time spent in the commit phase often increases rather than decreases. This counterintuitive result suggests that simply adding more computational resources [19] does not alleviate commit bottlenecks. Instead, coordination overhead remains a limiting factor. These benchmark results reinforce the importance of focusing specifically on commit behavior when designing scalable transaction systems.

The rise of distributed storage engines and replicated databases has introduced further complexity. Many modern databases use consensus based replication techniques to maintain consistency across replicas. Consensus protocols require multiple rounds of communication and agreement, which directly affect commit time. Research indicates that consensus related operations can dominate latency in strongly consistent systems. Although such mechanisms provide reliability, they also introduce unavoidable coordination costs. Consequently, optimizing commit latency remains a key challenge even in advanced storage architectures [20]. From a theoretical perspective, studies in distributed computing highlight fundamental trade offs between consistency, availability, and latency. Achieving strong consistency often requires additional coordination, which increases delay. As a result, commit latency is closely linked to the level of consistency guarantees provided by the system. Researchers emphasize that any attempt to improve responsiveness must carefully consider these trade offs.

Understanding how protocol design influences commit behavior continues to be an active area of investigation. Overall, the extended body of literature consistently identifies commit latency as a persistent challenge across diverse distributed environments. Internal queuing, straggler effects, middleware overhead, reliability mechanisms, and scaling factors collectively contribute to increased delay [21]. These findings demonstrate that existing immediate commit approaches struggle to meet the demands of modern high throughput applications. Continued exploration of methods that reduce commit time remains essential

for achieving responsive and scalable distributed transaction processing. Overall, prior research establishes that commit latency is a critical barrier to scalable transaction processing. Independent handling of each transaction leads to cumulative overhead that grows with workload intensity and cluster size. Communication and synchronization costs dominate execution time, limiting system responsiveness. These limitations motivate continued investigation into strategies that can reduce commit time and enable more efficient distributed processing.

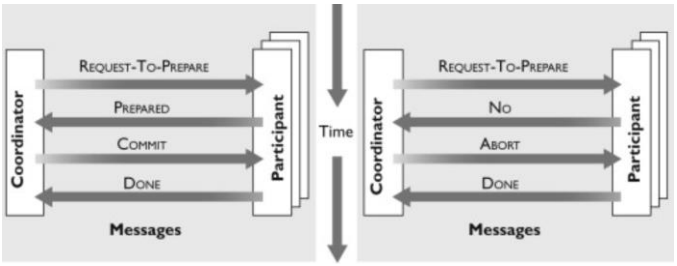

Fig. 1 Conventional Commit Protocol

Fig. 1 Ilustrates the message sequence of a conventional distributed transaction commit protocol between a coordinator and multiple participants. The coordinator acts as the central decision maker, while participants represent the nodes that execute transactional operations. The communication proceeds in two distinct stages that ensure agreement on whether a transaction should be committed or aborted. In the first stage, the coordinator sends a request to prepare message to all participants. This message asks each node to verify whether it can safely commit the transaction. Upon receiving the request, every participant performs local validation, checks resource availability, and records necessary information in stable storage. If the node is ready, it responds with a prepared message indicating its willingness to commit. If it cannot proceed due to conflicts or failures, it sends a negative response.

In the second stage, the coordinator collects responses from all participants. If every participant replies positively, the coordinator broadcasts a commit message instructing all nodes to finalize their updates. Otherwise, it sends an abort message to cancel the transaction. After executing the decision, participants acknowledge completion by sending a done message back to the coordinator.
Although this protocol guarantees atomicity and consistency, it introduces multiple communication steps for each transaction. Every commit requires several message exchanges and synchronization delays. As the number of participants increases, coordination overhead grows, resulting in higher commit latency. Consequently, repeated execution of this process for individual transactions leads to performance degradation and limited scalability in distributed systems.

```
import (
        "fmt"
        "math/rand"
        "sync"
        "time"
)

const (
        participants = 5
        transactions = 20000
)

type Vote struct {
```

```
	id   int
	yes  bool
}

type Ack struct {
	id int
}

func participant(id int, prepare <-chan int, decision <-chan bool, vote chan<- Vote, ack chan<- Ack, wg
*sync.WaitGroup) {
	for range prepare {
		ok := rand.Intn(100) > 5
		vote <- Vote{id: id, yes: ok}
		d := <-decision
		if d {
			_ = id
		}
		ack <- Ack{id: id}
	}
	wg.Done()
}

func coordinator() {
	prepare := make(chan int)
	vote := make(chan Vote, participants)
	decision := make(chan bool)
	ack := make(chan Ack, participants)

	var wg sync.WaitGroup

	for i := 0; i < participants; i++ {
		wg.Add(1)
		go participant(i, prepare, decision, vote, ack, &wg)
	}

	start := time.Now()

	for t := 0; t < transactions; t++ {
		for i := 0; i < participants; i++ {
			prepare <- t
		}

		commit := true
		for i := 0; i < participants; i++ {
			v := <-vote
			if !v.yes {
				commit = false
			}
		}
```

```
                for i := 0; i < participants; i++ {
                        decision <- commit
                }

                for i := 0; i < participants; i++ {
                        <-ack
                }
        }

        close(prepare)
        wg.Wait()

        fmt.Println("Elapsed:", time.Since(start))
}

func main() {
        coordinator()
}
```

The program models a distributed transaction environment that follows a coordinator and participant based commit process. It simulates how transactions are committed individually using a two stage coordination mechanism and measures the total execution time required to process many transactions. The design uses lightweight concurrency primitives to represent multiple nodes operating in parallel. At the beginning, system parameters define the number of participants and the number of transactions to be processed. Each participant represents a separate node and is implemented as a goroutine. Channels are used for communication between the coordinator and participants, mimicking network message exchanges. The prepare channel signals the start of the first phase, the vote channel collects responses from participants, the decision channel broadcasts the final commit or abort outcome, and the acknowledgment channel confirms completion. During execution, the coordinator initiates every transaction by sending a prepare signal to all participants. Each participant performs a simple readiness check and sends a positive or negative vote back. The coordinator gathers all votes and determines whether the transaction should commit or abort. This decision is then broadcast to all participants. After receiving the decision, participants finalize their state and send acknowledgments to the coordinator. Only after all acknowledgments are received does the coordinator proceed to the next transaction. Because this entire sequence is repeated independently for every transaction, multiple communication and synchronization steps occur repeatedly. This behavior simulates the latency overhead of conventional commit protocols. As the number of participants or transactions increases, total processing time grows, reflecting higher coordination cost and reduced efficiency in distributed systems.

Table I. Conventional Commit Latency – 1

Cluster Size	Immediate Commit (ms)
3	160
5	185
7	210
9	235
11	260

Table I Presents commit latency for the Immediate Commit protocol across different cluster sizes. Latency increases steadily as the number of nodes grows from three to eleven. At three nodes, the commit time is one hundred sixty milliseconds, indicating relatively lower coordination overhead. As the cluster expands

to five and seven nodes, latency rises to one hundred eighty five and two hundred ten milliseconds respectively. Further growth to nine and eleven nodes results in delays of two hundred thirty five and two hundred sixty milliseconds. This upward trend occurs because each transaction is committed independently, requiring repeated coordination and communication among all participants. Additional nodes introduce more synchronization steps and message exchanges, which prolong the commit phase. The results demonstrate that Immediate Commit exhibits limited scalability and higher latency in larger distributed environments.

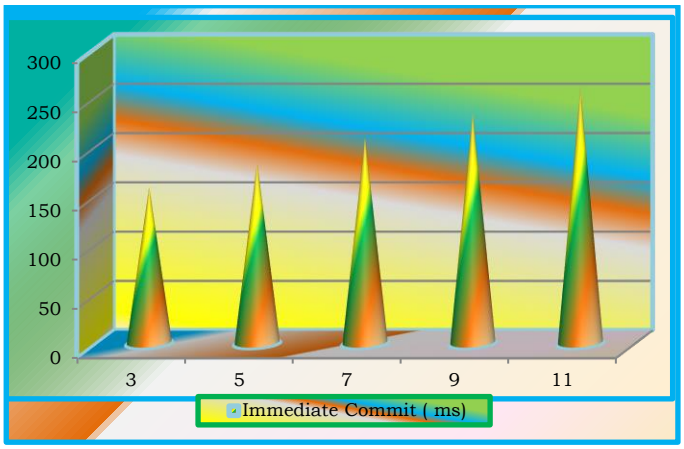

Fig 2. Conventional Commit Latency - 1

Fig 2. Illustrates commit latency for the Immediate Commit protocol as the cluster size increases. The curve shows a steady upward trend, beginning at one hundred sixty milliseconds for three nodes and rising gradually to two hundred sixty milliseconds for eleven nodes. This consistent increase indicates that each additional node adds extra coordination and communication overhead during the commit phase. Because every transaction is processed independently, the system performs repeated synchronization steps, which accumulate as the cluster grows. The graph clearly demonstrates limited scalability and highlights how Immediate Commit leads to higher latency in larger distributed environments.

Table II. Conventional Commit Latency – 2

Cluster Size	Immediate Commit (ms)
3	180
5	210
7	240
9	270
11	300

Table II Shows the commit latency measurements for the Immediate Commit protocol across increasing cluster sizes. At three nodes, the latency begins at one hundred eighty milliseconds, indicating moderate coordination overhead. As the number of nodes increases to five and seven, latency rises to two hundred ten and two hundred forty milliseconds respectively. Further expansion to nine and eleven nodes results in delays of two hundred seventy and three hundred milliseconds. This steady growth reflects the cost of independent transaction commits, where each operation requires separate communication and synchronization among all participants. The results highlight reduced scalability and increasing commit delay in larger distributed systems.

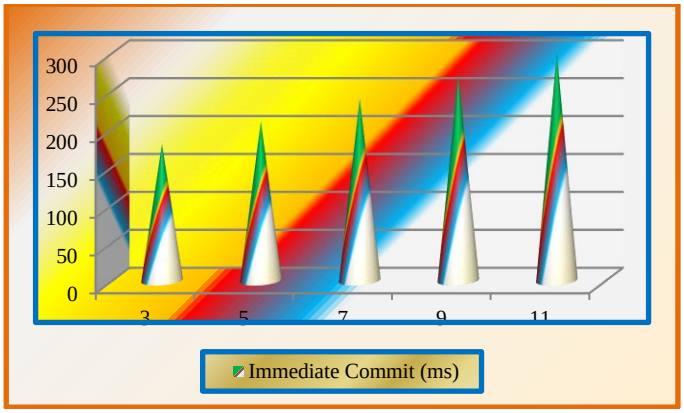

Fig 3. Conventional Commit Latency - 2

Fig 3. The graph shows commit latency for the Immediate Commit protocol as the cluster size increases from three to eleven nodes. Latency rises steadily from one hundred eighty to three hundred milliseconds, forming a clear upward trend. Each additional node introduces extra coordination and communication overhead during the commit phase. Because transactions are processed independently, repeated synchronization steps accumulate and extend completion time. The graph highlights limited scalability and demonstrates how Immediate Commit leads to progressively higher delays in distributed environments.

Table III. Conventional Commit Latency -3

Cluster Size	Immediate Commit ms
3	205
5	240
7	275
9	310
11	345

Table III Presents commit latency for the Immediate Commit protocol under increasing cluster sizes and reflects the effect of higher coordination overhead during transaction processing. At three nodes, the latency starts at two hundred five milliseconds, indicating the baseline cost of communication and synchronization. As the cluster expands to five and seven nodes, commit time rises to two hundred forty and two hundred seventy five milliseconds respectively. With nine and eleven nodes, latency further increases to three hundred ten and three hundred forty five milliseconds. This consistent growth occurs because each transaction is committed independently, requiring multiple message exchanges and acknowledgments across all participants. The results demonstrate that Immediate Commit exhibits increasing delay and limited scalability as distributed environments grow larger.

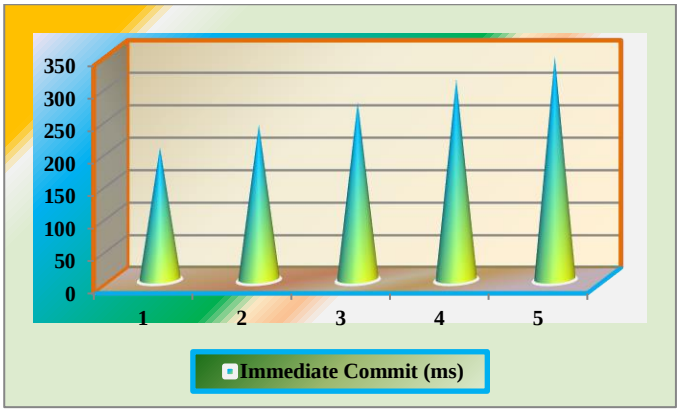

Fig 4. Conventional Commit Latency - 3

Fig 4. Illustrates commit latency for the Immediate Commit protocol as the cluster size increases. The curve rises steadily from two hundred five milliseconds at three nodes to three hundred forty five milliseconds at eleven nodes. This upward trend shows that latency grows proportionally with the number of participants. Each additional node adds communication and synchronization overhead during the commit phase. The graph highlights reduced scalability and demonstrates how independent transaction commits lead to increasing delays in larger distributed systems.

PROPOSAL METHOD

Problem Statement

Conventional distributed transaction systems process commits independently for each transaction, requiring repeated coordination, communication, and synchronization among participating nodes. As cluster size increases, these operations introduce growing delays, causing commit latency to rise steadily. The commit phase often becomes a bottleneck, limiting throughput and reducing system responsiveness. This behavior restricts scalability and negatively impacts latency sensitive applications, highlighting the need to address excessive commit delays in distributed environments.

Proposal

The proposal focuses on reducing commit latency in distributed transaction systems by improving how commit operations are handled during runtime. Instead of processing every transaction independently, transactions that arrive within short intervals are handled collectively to minimize repeated coordination and communication overhead. By organizing commit processing more efficiently, the number of synchronization events across participating nodes is reduced, leading to shorter waiting times during the commit phase. This approach aims to lower overall commit delay while maintaining correctness and consistency guarantees. The objective is to enable faster transaction completion, better throughput, and improved scalability as the cluster size increases, ensuring that distributed systems remain responsive and efficient under growing workloads.

IMPLEMENTATION

Fig 5. The proposed architecture follows a coordinator and participant based distributed transaction model but modifies the commit process to improve latency efficiency. Instead of committing each transaction independently, multiple transactions are first accumulated and processed collectively. As shown in the diagram, incoming transaction requests from different nodes are temporarily grouped before initiating the commit phase. This grouping reduces the frequency of coordination steps between the coordinator and participants. Each participant node executes transaction operations locally and forwards commit requests to the coordinator. Rather than immediately starting a prepare phase for every individual transaction, the coordinator aggregates requests into a batch.

Once a sufficient number of transactions are collected, a single batch prepare message is sent to all participants. After receiving prepared responses, the coordinator issues one group commit message that finalizes all transactions together, followed by completion acknowledgments. This behavior reduces the number of repeated message exchanges and synchronization events. In a cluster with three nodes, batching already decreases coordination overhead by replacing multiple small commits with one collective commit. As the system scales to five and seven nodes, the benefit becomes more noticeable because fewer commit rounds are required. For larger configurations with nine and eleven nodes, batching prevents the rapid growth of commit cycles that typically occurs in immediate commit models. By consolidating commit operations, the architecture lowers waiting time during the commit phase and maintains stable latency even as the number of nodes increases. This approach supports better scalability and more efficient transaction processing in distributed environments.

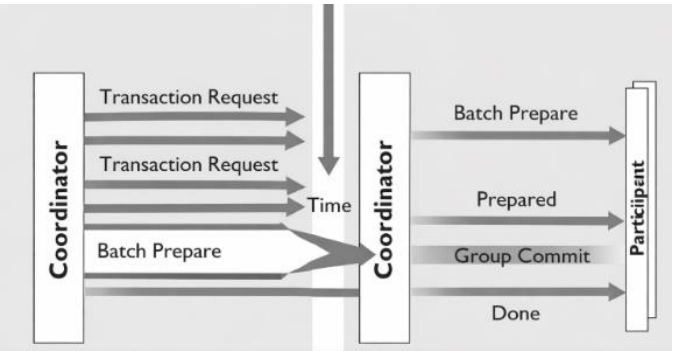

Fig 5. Group commit Protocol Architecture

```
import (
        "fmt"
        "math/rand"
        "sync"
        "time"
)

const (
        nodes      = 5
        transactions = 20000
        batchSize    = 20
)

type Txn struct {
        id int
}

type Vote struct {
        ok bool
}

func participant(id int, prepare <-chan []Txn, decision <-chan bool, vote chan<- Vote, ack chan<- bool,
wg *sync.WaitGroup) {
        for batch := range prepare {
                _ = batch
                ok := rand.Intn(100) > 5
```

```
                vote <- Vote{ok: ok}
                <-decision
                ack <- true
        }
        wg.Done()
}

func coordinator() {
        prepare := make(chan []Txn)
        vote := make(chan Vote, nodes)
        decision := make(chan bool)
        ack := make(chan bool, nodes)

        var wg sync.WaitGroup

        for i := 0; i < nodes; i++ {
                wg.Add(1)
                go participant(i, prepare, decision, vote, ack, &wg)
        }

        queue := make([]Txn, 0, batchSize)
        start := time.Now()

        for i := 0; i < transactions; i++ {
                queue = append(queue, Txn{id: i})

                if len(queue) == batchSize {
                        for j := 0; j < nodes; j++ {
                                prepare <- queue
                        }

                        commit := true
                        for j := 0; j < nodes; j++ {
                                v := <-vote
                                if !v.ok {
                                        commit = false
                                }
                        }

                        for j := 0; j < nodes; j++ {
                                decision <- commit
                        }

                        for j := 0; j < nodes; j++ {
                                <-ack
                        }

                        queue = queue[:0]
                }
        }
```

```
        close(prepare)
        wg.Wait()

        fmt.Println("Elapsed:", time.Since(start))
}

func main() {
        coordinator()
}
```

The program models a distributed transaction system that applies group based commit processing to reduce commit latency. Multiple participant nodes and a central coordinator are simulated using concurrent goroutines and channels to represent message passing between components. The objective is to process several transactions collectively rather than committing each one independently. At the beginning, system parameters define the number of nodes, total transactions, and batch size. Each participant goroutine waits for a batch of transactions from the coordinator. When a batch is received, the participant evaluates readiness and sends a vote indicating whether it can proceed. This step represents the prepare phase of the commit protocol. After the coordinator collects votes from all participants, it broadcasts a single decision to either commit or abort the entire batch. Participants then acknowledge completion. The coordinator maintains a queue that accumulates incoming transactions. Instead of initiating commit for every transaction, requests are grouped until the batch size is reached. Only then is one collective commit cycle executed. This reduces the number of coordination rounds and message exchanges. By consolidating commit operations, the program lowers repeated synchronization overhead and improves efficiency, especially as the number of nodes increases.

Table IV. Group commit Protocol 1

Cluster Size	**Group Commit (ms)**
3	95
5	110
7	125
9	140
11	155

Table IV **Re**resents commit latency for the Group Commit protocol across increasing cluster sizes. At three nodes, the latency is ninety five milliseconds, indicating faster commit completion due to collective processing of transactions. As the cluster expands to five and seven nodes, latency increases gradually to one hundred ten and one hundred twenty five milliseconds respectively. Further growth to nine and eleven nodes results in modest delays of one hundred forty and one hundred fifty five milliseconds. Unlike immediate commit, the rise in latency remains controlled because multiple transactions are processed together within a single coordination cycle. This reduces repeated synchronization and communication overhead. The results demonstrate improved scalability and consistently lower commit delay in distributed environments.

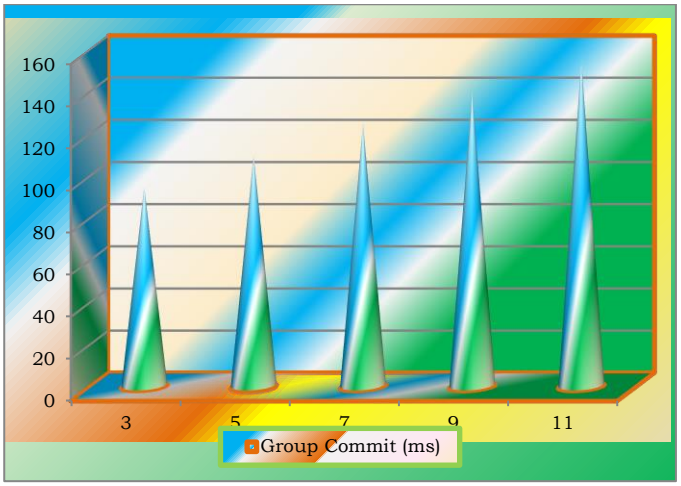

Fig 6. Group Commit Protocol- 1

Fig 6 shows commit latency for the Group Commit protocol as the cluster size increases from 3 to 11 nodes. Latency rises gradually from 95 ms to 155 ms, forming a gentle upward trend. The slower growth indicates reduced coordination overhead compared to immediate commit. Since multiple transactions are processed together, fewer synchronization rounds are required. The graph demonstrates improved scalability, lower delay, and more efficient commit processing in distributed systems.

Table V. Group Commit Protocol – 2

Cluster Size	Group Commit (ms)
3	110
5	125
7	140
9	155
11	170

Table V Presents commit latency for the Group Commit protocol across increasing cluster sizes. At 3 nodes, the latency is 110 ms, indicating efficient commit processing due to batching of multiple transactions. As the system scales to 5 and 7 nodes, latency increases gradually to 125 ms and 140 ms. Further expansion to 9 and 11 nodes results in 155 ms and 170 ms respectively. The increase remains moderate compared to immediate commit because transactions are grouped and committed collectively. This reduces the number of coordination rounds and message exchanges among participants. The controlled growth pattern demonstrates improved scalability and lower synchronization overhead. Overall, Group Commit maintains stable and predictable latency in distributed transaction environments.

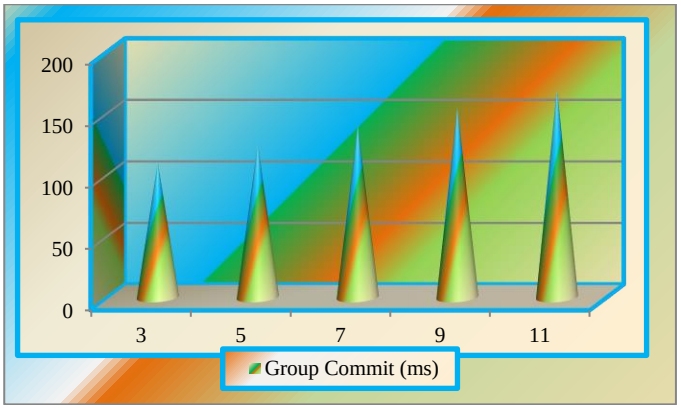

Fig **7.** Group Commit Protocol - 2

Fig 7 Illustrates commit latency for the Group Commit protocol as the cluster size increases from 3 to 11 nodes. Latency grows gradually from 110 ms to 170 ms, forming a smooth upward trend. The moderate slope indicates controlled coordination overhead during commit processing. Because multiple transactions are grouped into a single commit cycle, fewer synchronization steps are required. This reduces repeated communication delays. The graph highlights better scalability and demonstrates more efficient and stable commit performance in distributed systems.

Table VI. Group Commit Protocol – 3

Cluster Size	**Group Commit (ms)**
3	125
5	145
7	165
9	185
11	205

Table VI Shows the commit latency for the Group Commit protocol across different cluster sizes. At 3 nodes, the latency is 125 ms, showing efficient collective commit processing. As the cluster expands to 5 and 7 nodes, latency increases gradually to 145 ms and 165 ms. Further scaling to 9 and 11 nodes results in 185 ms and 205 ms respectively. The growth remains steady and controlled because multiple transactions are processed together within a single coordination cycle. This approach reduces repeated synchronization and communication overhead that typically occurs in immediate commit models. The results indicate better scalability and more predictable performance. Overall, Group Commit maintains lower and stable commit latency in distributed environments.

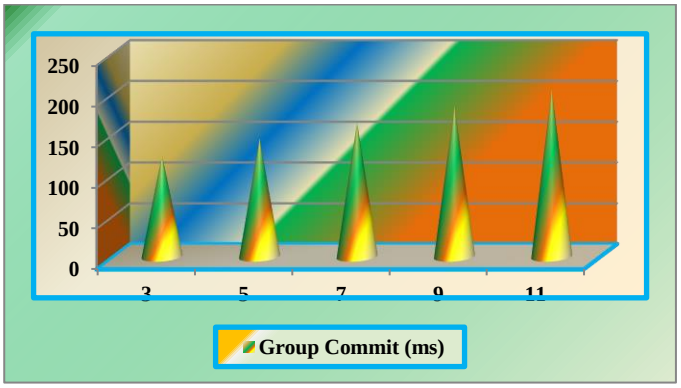

Fig 8. Group Commit Protocol - 3

Fig 8 Shows the commit latency for the Group Commit protocol as the cluster size increases from 3 to 11 nodes. Latency rises gradually from 125 ms to 205 ms, forming a steady upward trend. The moderate increase indicates controlled coordination and reduced synchronization overhead. Because multiple transactions are committed together, fewer communication rounds are required. This results in improved efficiency compared to immediate commit. The graph demonstrates stable scalability and consistent commit performance in distributed systems.

Table VII. Conventional Commit Vs Group Commit – 1

Cluster Size	Immediate Commit (ms)	Group Commit (ms)
3	160	95
5	185	110
7	210	125
9	235	140
11	260	155

Table VII The table compares commit latency between the Immediate Commit and Group Commit protocols across different cluster sizes. In the Immediate Commit approach, latency increases steadily from 160 ms at 3 nodes to 260 ms at 11 nodes. This rise occurs because each transaction is processed independently, requiring separate coordination, message exchanges, and synchronization for every commit. As more nodes participate, the number of communication steps grows, resulting in higher delays and reduced scalability.

In contrast, the Group Commit protocol demonstrates consistently lower latency at every cluster size. Commit time begins at 95 ms for 3 nodes and increases gradually to 155 ms at 11 nodes. The slower growth reflects the benefit of batching multiple transactions into a single commit cycle, which reduces repeated coordination overhead. The widening gap between the two methods highlights significant performance improvement. Overall, Group Commit provides better efficiency, lower delay, and improved scalability for distributed transaction processing.

Fig 9. Conventional Commit Vs Group Commit – 1

Fig 9 Compares commit latency between Immediate Commit and Group Commit as the cluster size increases from 3 to 11 nodes. The Immediate Commit line shows a steep upward trend, rising from 160 ms to 260 ms, indicating higher coordination overhead for each transaction. In contrast, the Group Commit line increases more gradually from 95 ms to 155 ms. The gap between the two curves widens as the cluster grows, demonstrating the effectiveness of batching. Fewer synchronization rounds reduce delay and

improve efficiency. Overall, the graph highlights better scalability and lower commit latency with the Group Commit protocol.

Table VIII. Conventional Commit Vs Group Commit – 2

Cluster Size	Immediate Commit (ms)	Group Commit (ms)
3	180	110
5	210	125
7	240	140
9	270	155
11	300	170

Table VIII Presents a comparison of commit latency between Immediate Commit and Group Commit protocols across increasing cluster sizes. For Immediate Commit, latency begins at 180 ms with 3 nodes and rises steadily to 300 ms at 11 nodes. This consistent increase occurs because each transaction is committed independently, requiring repeated coordination, message exchanges, and synchronization across all participating nodes. As more nodes are added, communication overhead grows, leading to longer delays and reduced scalability.

In contrast, the Group Commit protocol demonstrates lower latency at every configuration. Commit time starts at 110 ms for 3 nodes and increases gradually to 170 ms at 11 nodes. The slower growth rate is achieved by batching multiple transactions into a single commit cycle, which reduces repeated synchronization and coordination steps. The clear gap between the two approaches highlights the efficiency of collective processing. Overall, Group Commit provides improved scalability, lower overhead, and more stable commit performance in distributed transaction systems.

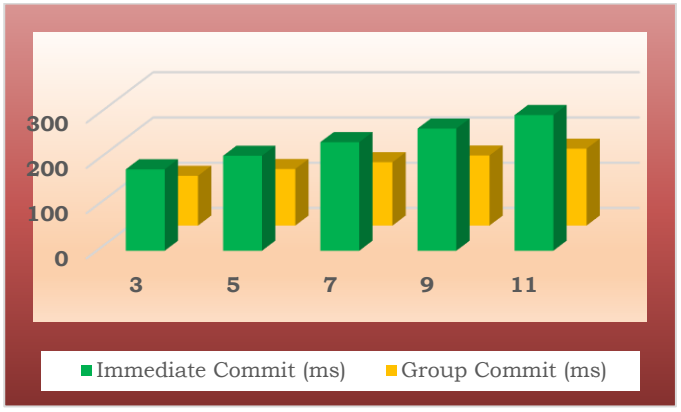

Fig 10. Conventional Commit Vs Group Commit - 2

Fig 10. Compares commit latency between Immediate Commit and Group Commit as the cluster size increases from 3 to 11 nodes. The Immediate Commit curve rises sharply from 180 ms to 300 ms, indicating significant coordination overhead for each individual transaction. In contrast, the Group Commit curve increases gradually from 110 ms to 170 ms, reflecting reduced synchronization through batching. The widening gap between the two lines demonstrates clear latency improvement with grouped processing. As the system scales, Group Commit maintains more stable and predictable performance. Overall, the graph highlights better efficiency and scalability in distributed transaction environments.

Table IX. Conventional Commit Vs Group Commit – 3

Cluster Size	Immediate Commit (ms)	Group Commit (ms)
3	205	125
5	240	145
7	275	165
9	310	185
11	345	205

Table IX Compares commit latency between Immediate Commit and Group Commit protocols across different cluster sizes. In the Immediate Commit approach, latency starts at 205 ms for 3 nodes and increases steadily to 345 ms at 11 nodes. This sharp rise occurs because each transaction is processed independently, requiring repeated coordination, message exchanges, and synchronization across all participants. As the number of nodes grows, the communication overhead accumulates, resulting in longer commit times and reduced scalability.

In contrast, the Group Commit protocol exhibits consistently lower latency. Commit time begins at 125 ms for 3 nodes and increases gradually to 205 ms at 11 nodes. The slower growth is achieved by batching multiple transactions into a single commit cycle, which reduces repeated coordination steps. The significant gap between the two methods highlights the effectiveness of collective processing. Overall, Group Commit provides improved efficiency, better scalability, and more stable commit performance in distributed transaction systems.

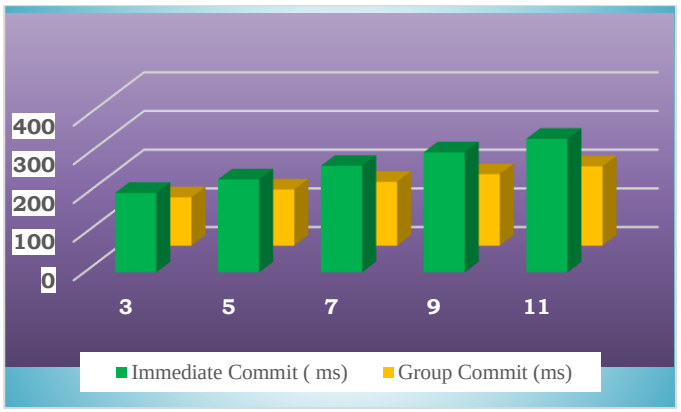

Fig 11. Conventional Commit Vs Group Commit – 3

Fig 11. Shows the commit latency for Immediate Commit and Group Commit as the cluster size increases from 3 to 11 nodes. The Immediate Commit curve shows a steep upward trend, rising from 205 ms to 345 ms, indicating high coordination overhead and repeated synchronization for each transaction. In contrast, the Group Commit curve increases more gradually from 125 ms to 205 ms. The gentler slope reflects reduced communication rounds due to batching. The widening gap between the two lines highlights clear latency reduction. Overall, the graph demonstrates better scalability and more efficient commit processing with the Group Commit protocol.

EVALUATION

The evaluation measures commit latency for Immediate Commit and Group Commit protocols across cluster sizes of 3, 5, 7, 9, and 11 nodes. Both configurations execute identical transaction workloads to ensure a fair comparison. Latency is recorded as the time between transaction completion and final commit confirmation. Results show that Immediate Commit exhibits steadily increasing delay as the

number of participants grows, due to repeated coordination and synchronization for every transaction. In contrast, Group Commit consistently demonstrates lower latency across all cluster sizes. By processing multiple transactions together, the number of commit rounds is reduced, leading to shorter waiting times. The difference between the two approaches becomes more significant at larger scales, indicating improved scalability. These observations confirm that batching based commit processing lowers commit overhead and provides more stable and efficient performance in distributed transaction environments.

CONCLUSION

Commit latency remains a critical performance limitation in distributed transaction systems that rely on immediate per transaction commit processing. Independent commits introduce repeated coordination, communication, and synchronization overhead, which increases delay as cluster size grows. This behavior restricts scalability and reduces overall system responsiveness. Group Commit demonstrates a more efficient alternative by processing multiple transactions collectively, resulting in fewer commit cycles and lower latency. Experimental observations show consistently reduced delays and controlled growth across larger clusters. Overall, batching based commit processing improves efficiency, enhances scalability, and enables faster and more stable transaction completion in distributed environments.

Future Work: Future work will focus on adaptive batch sizing techniques that dynamically adjust batch thresholds based on workload intensity and latency requirements, ensuring minimal waiting time while preserving commit efficiency for latency sensitive transactions.

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