Cyberscope

Audit Report

Elar

October 2023

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Overview

Elar is a robust replicated state machine designed to uphold a secure, local copy of a cryptographic ledger. It effectively facilitates the processing of transactions while ensuring consensus among a designated group of peers. Elar's foundation is rooted in the implementation of the Stellar Consensus Protocol, a federated consensus protocol renowned for its reliability. Elar is built using C++14 and boasts cross-platform compatibility, making it compatible with Linux, OSX, and Windows operating systems.

Architecture

In our code audit, we've examined the process-level architecture of the Elar system. The application consists of several key components, each serving a distinct role in the system's operation. This comprehensive architecture encompasses components responsible for ledger management, peer-to-peer communication, transaction synchronization, transaction processing, cryptographic operations, and database management. Two specific components that may appear slightly obscure in naming are "BucketList" and "SCP," each with its unique purpose and significance within the system.

Our review of the process-level architecture of the Elar system underscores the significance of each component in contributing to the system's overall functionality and reliability. The clear separation of responsibilities among these components, along with the unique roles played by "BucketList" and "SCP," demonstrates a well-thought-out and organized architecture designed to meet the demands of a complex distributed system.

Review of Network-Level

In our code audit, we've analyzed the network-level architecture of the Elar system, particularly focusing on the role and design considerations of validators within the network. The overarching philosophy guiding the architecture is to maintain simplicity within validators while offloading specific responsibilities to other parts of the system.

The network-level architecture of Elar emphasizes simplicity and efficient resource utilization. Validators are designed with a specific focus on offloading responsibilities to other parts of the system that are better suited for specific tasks. By maintaining an even system-load profile and prioritizing statelessness, the architecture seeks to provide a stable and reliable network environment. These architectural principles align with the goals of scalability, performance, and robustness within a distributed system.

Components

Certainly, here's a rephrased version of the information about the major components of the Elar system without numeric ordering:

Herder

Herder plays a pivotal role in bridging SCP with the broader stellar-core system. It offers concrete implementations of essential methods used by SCP to interact with peers, compare values, validate signatures, and more. Herder often delegates tasks to other components as needed. Detailed insights can be found in the src/herder/readme.md documentation.

Overlay

Overlay is responsible for establishing and maintaining connections with known peers and managing message propagation within the network. It efficiently disseminates messages and retrieves necessary data from peers to facilitate consensus. Additional details can be explored in the src/overlay/readme.md section. Other data downloads are handled separately, as explained in ./architecture.md.

Ledger

The Ledger component is in charge of applying transaction sets externalized by SCP. It also relays externalization events to various system components, such as updating ledger entries, triggering history data publishing, and notifying the overlay system about message flooding. The src/ledger/readme.md provides comprehensive information on its functionality.

History

History serves as the data publisher, archiving transaction and ledger entries to off-site permanent storage for auditing purposes and as a source of catch-up data for other nodes. When a node falls behind, the history system retrieves catch-up data and submits it to the

Ledger component, following a two-step process: first for security verification and then for application. Refer to src/history/readme.md for further insights.

BucketList

BucketList is responsible for organizing ledger entries on disk, optimizing them for hashing and block-catch-up processes. It coordinates the hashing and deduplication of buckets through multiple background threads. Explore src/bucket/readme.md for detailed information on its role and operations.

Transactions

Transactions encompass the various transaction types within the system. Detailed documentation on the implementation of different transaction types can be found in the src/transactions/readme.md section.

These component descriptions provide an overview of the major building blocks of the Elar system, each contributing to its functionality and overall operation. Further documentation within each component's respective readme.md directory can offer more in-depth insights into their specific functionalities and interactions within the system.

Stellar Consensus Protocol (SCP)

The SCP component serves as our tailored implementation of the Stellar Consensus Protocol. It operates independently from the rest of the system, handling candidate black-box values and signaling consensus achievements across the network. For a detailed explanation, please refer to the documentation in the src/scp/readme.md directory.

Review of the Stellar Consensus Protocol (SCP) Subsystem

In our code review of the Elar system, we have evaluated the SCP subsystem—an abstract implementation of the Stellar Consensus Protocol (SCP). SCP is a federated Byzantine agreement protocol, integral to the system's functionality. Notably, SCP is designed to drive a distributed system based on the concept of a "replicated state machine." It's worth mentioning that SCP is intentionally designed without tying it to specific concepts like "slot" or "value," allowing for flexibility in its application across different contexts.

Benefits of Subsystem Separation

One notable aspect we've observed is the deliberate separation of the SCP subsystem from the rest of the system. This architectural choice serves several valuable purposes. Firstly, it simplifies the modeling of SCP, making it more manageable to compare with the original protocol paper, facilitating auditability, and ensuring correctness. Moreover, this separation sets the stage for potential future extraction and reuse of SCP in various program contexts—a forward-looking strategy that enhances code versatility.

Implementation of Consensus with SCP

Our review revealed that to implement consensus using SCP, modules within the system are expected to create subclasses of the SCPDriver class. These subclasses must provide concrete implementations for abstract methods responsible for handling SCP-generated events. The SCPDriver class serves as the primary interface for receiving incoming messages related to SCP consensus. This modular approach facilitates code maintainability and extensibility.

Protocol Definitions and XDR

In our assessment, we've also noted that the SCP protocol messages are formally defined in XDR format within the Stellar-SCP.x file. However, for practical development purposes, much of the focus tends to be on modifying Stellar-types.x. This file houses essential base

types used throughout the implementation, such as hash and NodeID, which represent a node's identity.

Herder in stellar-core

Within the stellar-core program, we found a significant component known as Herder. Herder serves as the sole subclass of SCPDriver in this context, providing a specific interpretation of "slot" and "value." It plays a crucial role in connecting SCP with a designated broadcast communication medium (Overlay) and a specific replicated state machine (LedgerManager). Our assessment found Herder to be a key bridge in the system's architecture, facilitating SCP's integration with other core components.

For Further Insight

For a comprehensive understanding of the SCP protocol itself, we recommend referring to the original SCP paper. It provides extensive insights into the protocol's design and operation, serving as a valuable reference point for developers and auditors.

In conclusion, the separation and abstraction strategies employed within the SCP subsystem contribute significantly to the codebase's modularity, auditability, and potential for future reuse—a commendable approach that aligns well with best practices in code design and architecture.

Herder - Concrete Implementation of SCP

In our code review, we have closely examined the Herder component, specifically the HerderSCPDriver. This is a significant part of the Elar system, providing a concrete implementation of the Stellar Consensus Protocol (SCP). Unlike the abstract SCP protocol, HerderSCPDriver operates in terms of concepts familiar to Stellar developers, such as "transaction sets" and "ledger numbers.

Our assessment of HerderSCPDriver highlights its crucial role in making SCP actionable and relevant within the Elar system. By serving as a subclass of SCPDriver and implementing SCP in concrete terms, HerderSCPDriver plays a pivotal role in the overall functionality of Elar. It transforms SCP from an abstract concept into a practical and functional component within the system, enabling it to operate effectively in the context of "transaction sets" and "ledger numbers" as per Stellar's terminology. This alignment with real-world Stellar requirements is a key factor in the success of the Herder component within Elar.

Ledger

In our code audit, we've examined the concept of a ledger in the Elar system, which represents the state of the Stellar universe at a specific point in time. Here, we outline the key aspects of ledger management:

- Genesis Ledger
- Consensus and Transaction Sets
- Cryptographic Linkage and Ledger Chain
- Sequence Number Definition

The sequence number of a ledger is defined recursively based on its position in the ledger chain:

The genesis ledger is assigned a sequence number of 1.

Subsequent ledgers are assigned sequence numbers incrementally, starting from the genesis ledger. A ledger directly derived from a ledger with sequence number "n" is assigned a sequence number of "n+1."

This ledger management system provides a clear and secure mechanism for tracking the state of the Stellar universe over time. The use of cryptographic linkage and sequence numbers ensures the integrity of the ledger history, while SCP consensus rounds determine the application of transaction sets, allowing the universe to evolve and progress from one ledger to the next.

Historical Records Management

In our code audit, we've explored the management of historical records within the Elar system. Here's an overview of how historical records are handled

Responsibility of the History Module

The History module is primarily responsible for interfacing with "history archives." These archives are loosely defined as storage locations where flat files containing historical records can be stored and retrieved.

User-Defined History Archives

Users have the flexibility to define history archives by adding sections of the form [HISTORY.name] to the configuration file. Each history archive is identified by a name, which serves as a symbolic logging prefix. Multiple history archives can coexist within a single configuration file.

Configuring Get and Put Commands

For each history archive defined in the configuration, users can specify "get" and "put" commands. These commands define subprocesses that the stellar-core will execute to either deposit historical records into the archive or retrieve records from it. The commands are specified in the form of string templates, with placeholders {0} and {1} representing the files to be transmitted or received.

History Generation and Multiple Peers

Historical records are generated as part of the operation of the LedgerManager. It's important to note that multiple peers within the Elar network can publish history to multiple archives. This decentralization ensures redundancy and robustness in historical record storage.

Catchup Mode

In cases where the LedgerManager detects that it has fallen out of synchronization with its peers, it enters a "catchup mode." During this mode, the history module downloads and replays historical records from a history archive to the LedgerManager. This process aims to bring the LedgerManager back into synchronization with its peers.

This approach to managing historical records ensures the integrity and availability of historical data within the Elar system. By allowing users to configure history archives and define get/put commands, Elar offers flexibility in historical record management. The catchup mode is a critical feature that helps maintain synchronization with network peers, ensuring the consistency and reliability of historical data.

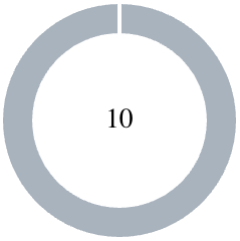
Buckets and the BucketList

In our code audit, we've explored the concept of buckets and the BucketList within the Elar system. These elements play a critical role in managing ledger entries efficiently. Here's a breakdown of how they function:

- Handling Large Sets of Ledger Entries
- Introduction of the BucketList
- BucketList Hash
- Checkpointing to History Storage
- Fast Catchup and Delta Application

The introduction of the BucketList and its hierarchical structure addresses the challenges of handling large sets of ledger entries efficiently. It enables the system to calculate cryptographic hashes, transmit minimal changes to peers during catchup, and maintain historical records for reference. This architectural approach enhances the integrity and performance of ledger management within the Elar system.

Findings Breakdown



Critical	0
Medium	0
Minor / Informative	10

Severity	Unresolved	Acknowledged	Resolved	Other
Critical	0	0	0	0
Medium	0	0	0	0
Minor / Informative	10	0	0	0

Diagnostics

Critical Medium Minor / Informative

Severity	Code	Description	Status
●	UCWNV	Unsigned Comparison with Negative Values	Unresolved
●	EEC	Enhancing Explicit Constructors	Unresolved
●	LCPC	Legacy C-Style Pointer Casting	Unresolved
●	PPBCR	Parameter Passed by Const Reference	Unresolved
●	DE	Duplicate Expressions	Unresolved
●	LVS	Local Variable Shadowing	Unresolved
●	ITOFC	Invariant True or False Conditions	Unresolved
●	OVS	Optimizing Variable Scope	Unresolved
●	ECR	Enhancing Const References	Unresolved
●	USA	Using STL algorithms	Unresolved

UCWNV - Unsigned Comparison with Negative Values

Criticality	Minor / Informative
Location	overlay/TCPPeer.cpp#L568
Status	Unresolved

Description

The codebase contains unsigned expressions that are being compared with negative values. Such comparisons can lead to unexpected and erroneous behavior due to the nature of unsigned data types, which cannot represent negative values.

```
if (length <= 0 ||
```

Recommendation

To address this finding, it is advisable to review the identified comparisons and ensure that they are appropriate for the intended logic. If the intent is to check for values less than zero, consider using a signed data type instead of unsigned.

EEC - Enhancing Explicit Constructors

Criticality	Minor / Informative
Location	bucket/BucketApplicator.h#L66bucket/BucketInputIterator.h#L49bucket/BucketList.h#L363,L391bucket/BucketManagerImpl.h#L95catchup/ApplyBufferedLedgersWork.h#L19catchup/CatchupManagerImpl.h#L56crypto/ByteSlice.h#L59,L63,L66,L70,L74crypto/CryptoError.h#L16database/Database.cpp#L139database/Database.h#L40,L107herder/Upgrades.h#L40herder/HerderImpl.h#L62,L297herder/HerderPersistenceImpl.h#L17herder/HerderSCPDriver.h#L158herder/QuorumTracker.h#L50herder/SurgePricingUtils.h#L112herder/TransactionQueue.cpp#L1152herder/TxQueueLimiter.h#L19herder/TxSetUtils.h#L19herder/TxSetFrame.cpp#L174history/FileTransferInfo.h#L31history/HistoryManagerImpl.h#L46historywork/GetHistoryArchiveStateWork.h#L29invariant/InvariantManagerImpl.h#L34ledger/InMemoryLedgerTxnRoot.h#L35ledger/InternalLedgerEntry.h#L73,L142ledger/LedgerCloseMetaFrame.h#L18ledger/LedgerManagerImpl.h#L113ledger/LedgerTxn.h#L350ledger/TrustLineWrapper.cpp#L21,L379main/ExternalQueue.h#L17main/CommandHandler.h#L32main/CommandLine.cpp#L114,L122,L130main/PersistentState.h#L18overlay/BanManagerImpl.h#L21overlay/Floodgate.h#L53overlay/FlowControl.h#L87overlay/Peer.h#L120overlay/PeerAuth.h#L39overlay/PeerDoor.h#L35overlay/OverlayManagerImpl.h#L132overlay/OverlayMetrics.h#L24overlay/SurveyManager.h#L26overlay/TxAdvertQueue.h#L30scp/BallotProtocol.h#L99scp/NominationProtocol.h#L88simulation/CoreTests.cpp#L476simulation/LoadGenerator.h#L78,L105simulation/Simulation.h#L127simulation/Simulation.cpp#L714test/FuzzerImpl.cpp#L344,L1012,L1041test/SimpleTestReporter.h#L14test/TestMarket.h#L65test/TestUtils.h#L38,L55test/TxTests.h#L32,L33,L34,L35,L38transactions/BumpFootprintExpirationOpFrame.cpp#L17transactions/CreatePassiveSellOfferOpFrame.h#L14transactions/InvokeHostFunctionOpFrame.cpp#L182transactions/RestoreFootprintOpFrame.cpp#L18transactions/TransactionMetaFrame.h#L17transactions/TransactionSQL.cpp#L31util/BitSet.h#L122,L126util/LogSlowExecution.h#L22util/Timer.h#L182,L253,L254,L282util/TmpDir.h#L17,L29util/TxResource.h#L36,L46util/XDRStream.h#L39
Status	Unresolved

Description

The codebase contians instances where a class has a constructor with a single argument that lacks the 'explicit' keyword. An implicit single-argument constructor can lead to unintended type conversions and potentially introduce ambiguity in code behavior.

```
ByteSlice(xdr::opaque_array<N> const& arr)
ByteSlice(xdr::msg_ptr const& p) : mData(p->data()), mSize(p->size())
ByteSlice(std::vector<uint8_t> const& bytes)
ByteSlice(std::string const& bytes)
ByteSlice(char const* str) : ByteSlice((void const*)str, strlen(str))
```

Recommendation

To address this finding, it is recommended to review and update the constructor by adding the 'explicit' keyword to make the constructor's behavior more explicit. Doing so prevents unintended implicit type conversions and enhances code clarity.

LCPC - Legacy C-Style Pointer Casting

Criticality	Minor / Informative
Location	crypto/ByteSlice.h#L74crypto/StrKey.cpp#L26,L67ledger/LedgerTxnConfigSettingSQL.cpp#L118ledger/LedgerTxnContractCodeSQL.cpp#L136ledger/LedgerTxnContractDataSQL.cpp#L170,L172,L174ledger/LedgerTxnOfferSQL.cpp#L803process/ProcessManagerImpl.cpp#L791
Status	Unresolved

Description

The codebase is using C-style pointer casting. C-style pointer casting is a legacy practice that can introduce potential type-related issues and compatibility concerns. To improve code safety and maintainability, it is recommended to replace C-style pointer casting with modern C++ casting mechanisms.

```
ByteSlice(char const* str) : ByteSlice((void const*)str, strlen(str))
```

Recommendation

To address this finding, developers should refactor the code to utilize safer alternatives, such as static_cast, dynamic_cast, or reinterpret_cast, as appropriate for the specific use case. These modern C++ casting operators provide better type-checking and are less error-prone than C-style casting.

Replacing C-style pointer casting with modern C++ casting operators aligns the code with contemporary best practices, enhances code safety, and reduces the likelihood of type-related bugs. It also promotes code readability and maintainability by making the type conversions more explicit and comprehensible.

PPBCR - Parameter Passed by Const Reference

Criticality	Minor / Informative
Location	main/CommandLine.cpp#L448main/Config.cpp#L1717main/PersistentState.cpp#L38simulation/Simulation.cpp#L736util/FileSystemException.h#L25util/FileSystemException.cpp#L35util/TxResource.h#L36
Status	Unresolved

Description

The codebase contains function parameters that are passed by value when they could be more efficiently passed by const reference. When a parameter is passed by value, a copy of the argument is created, potentially leading to unnecessary memory consumption and performance overhead.

```
Simulation::metricsSummary(string domain)
```

Recommendation

To address this finding, it is recommended to review the identified function parameters and update their declarations to accept const references where appropriate. This change not only conserves memory but also improves the efficiency of function calls, especially when dealing with complex or large data structures.

DE - Duplicate Expressions

Criticality	Minor / Informative
Location	herder/test/HerderTests.cpp:4926
Status	Unresolved

Description

This finding identifies instances within the code where the same expression or sub-expression is duplicated on both sides of a logical or relational operator. Duplicate expressions can lead to redundant calculations, negatively impacting code efficiency and maintainability.

```
auto lastDexOpsBroadcasted = dexOpsBroadcasted;
auto lastNonDexOpsBroadcasted = nonDexOpsBroadcasted;
simulation->crankForAtLeast(broadcastPeriod + delta, false);
auto dexOpsPerPeriod = dexOpsBroadcasted - lastDexOpsBroadcasted;
```

Recommendation

To address this finding, it is advisable to review and refactor the code to eliminate the duplication of expressions. This can be achieved by:

- Storing the result of the common expression in a variable and then using that variable on both sides of the operator.
- Ensuring that the expression is only evaluated once, improving code performance and reducing the likelihood of errors.

By eliminating duplicate expressions, the code becomes more concise, easier to understand, and less prone to inconsistencies or bugs introduced by unintentional changes to one of the duplicated expressions.

LVS - Local Variable Shadowing

Criticality	Minor / Informative
Location	herder/TxSetFrame.cpp#L393,L415herder/TxSetFrame.h#L141
Status	Unresolved

Description

This finding points out instances within the codebase where a local variable is overshadowing a variable from an outer function. Local variable shadowing occurs when a new variable declared within a nested scope shares the same name as a variable in an enclosing scope.

```
size_t encodedSize = xdr::xdr_argpack_size(xdrTxSet);
```

Recommendation

To address this finding, it is recommended to review and modify the variable naming within the affected scope to prevent shadowing. This can be accomplished by:

- Renaming the local variable to give it a distinct and meaningful name.
- Ensuring that the variable's name does not conflict with variables in outer functions.
- Maintaining clear and unambiguous variable naming conventions to enhance code readability and maintainability.

Resolving local variable shadowing issues helps prevent unintended behavior, potential bugs, and enhances the clarity of variable scoping in the codebase.

ITOFC - Invariant True or False Conditions

Criticality	Minor / Informative
Location	bucket/Bucket.cpp#L766,L781
Status	Unresolved

Description

The codenbase contians specific conditions that are identified as either perpetually true or perpetually false based on the context in which they are evaluated. Recognizing such invariant conditions is crucial as they can lead to suboptimal code execution or indicate unintended logic.

```
if (!ni || (oi && ni && !refersToSameEntry(key(*oi), key(*ni)) && cmp(*oi,
*ni)))
...
```

Recommendation

To address this finding, a thorough review of the identified conditions should be conducted to:

- Verify the correctness of the code logic.
- Ensure that the conditions align with the intended behavior.
- Modify or optimize the code as necessary to improve its efficiency or accuracy.

Identifying and addressing invariant conditions contributes to the overall code quality and correctness, enhancing the robustness and reliability of the software.

OVS - Optimizing Variable Scope

Criticality	Minor / Informative
Location	herder/HerderPersistenceImpl.cpp#306,333history/StateSnapshot.cpp#67ledger/LedgerTxn.cpp#2822main/ApplicationUtils.cpp#51overlay/BanManagerImpl.cpp#97overlay/PeerManager.cpp#190,584scp/NominationProtocol.cpp#92transactions/LiquidityPoolDepositOpFrame.cpp#104,105util/Scheduler.cpp#368
Status	Unresolved

Description

Within the codebase, there are instances where variable scopes can be refined to enhance code clarity and maintainability. The primary recommendation is to minimize the scope of variables to the narrowest context where they are needed, reducing the risk of unintended side effects and improving code readability.

```
auto nodeIDString = KeyUtils::toStrKey(nodeID);
{
    ...
    st.exchange(soci::use(nodeIDString));
    ...
}
...
std::string qset64, qSetHashHex;

qSetHashHex = binToHex(qSetHash);
...
{
    ZoneNamedN(selectSCPQuorumsZone, "select scpquorums", true);
    soci::statement st = (sess.prepare << "SELECT qset FROM scpquorums "
                                          "WHERE qsethash = :h",
                          soci::into(qset64), soci::use(qSetHashHex));
```

Recommendation

To address this finding, we recommend reviewing the identified variables and assessing if their scopes can be effectively reduced without compromising functionality. By doing so,

you can enhance code quality, readability, and maintainability, while also minimizing the potential for unintended side effects.

ECR - Enhancing Const References

Criticality	Minor / Informative
Location	bucket/BucketList.cpp#752catchup/CatchupWork.cpp#543herder/PendingEnvelopes.cpp#152,215,705herder/TxSetFrame.cpp#793,1046main/ApplicationImpl.cpp#428process/ProcessManagerImpl.cpp#271simulation/Simulation.cpp#362transactions/TransactionFrame.cpp#1307
Status	Unresolved

Description

The codebase is using variables that are initialized but do not afterward without declaring them as const. This enhancement pertains to variables that are not intended to be modified and can be declared as references to 'const' for improved code clarity and reduced risk of inadvertent alterations.

```
for (auto& pending : mPending)
{
    pending->mImpl->cancel(ABORT_ERROR_CODE);
}
...
char* p = static_cast<char*>(std::memchr(buf, '\n', sizeof(buf)));
...
```

Recommendation

By utilizing a 'const' reference in the parameter declaration, the compiler is informed that the specific variable remains constant within the function, preventing unintentional modifications. This practice not only enhances code maintainability but also contributes to safer and more predictable code, particularly in larger codebases and collaborative development environments.

USA - Using STL algorithms

Criticality	Minor / Informative
Location	bucket/BucketList.cpp#733crypto/SecretKey.cpp#122herder/QuorumIntersectionCheckerImpl.cpp#50,719,726herder/TransactionQueue.cpp#1161herder/TxSetFrame.cpp#158,551,693,652herder/TxSetUtils.cpp#54,74history/HistoryArchiveReportWork.cpp#49invariant/SponsorshipCountIsValid.cpp#232,243ledger/LedgerManagerImpl.cpp#1185ledger/LedgerTxnAccountSQL.cpp#612ledger/LedgerTxnContractCodeSQL.cpp#119ledger/LedgerTxnContractDataSQL.cpp#133,137ledger/NetworkConfig.cpp#774,1107main/ApplicationUtils.cpp#816main/CommandLine.cpp#453,682main/Config.cpp#1073process/ProcessManagerImpl.cpp#206scp/BallotProtocol.cpp#1434scp/LocalNode.cpp#75,82,117scp/QuorumSetUtils.cpp#106scp/Slot.cpp#298simulation/Simulation.cpp#153,161transactions/BumpFootprintExpirationOpFrame.cpp#135transactions/CreateClaimableBalanceOpFrame.cpp#276transactions/RestoreFootprintOpFrame.cpp#145transactions/SignatureChecker.cpp#150transactions/TransactionFrame.cpp#412,953,572,659,666,1014transactions/TransactionUtils.cpp#1486util/TxResource.cpp#69util/types.cpp#79
Status	Unresolved

Description

The repository is using row loops instead of the Standard Template Library (STL) algorithms. The absence of STL algorithms in favor of custom loop implementations can introduce challenges in code readability, maintainability, and reliability.

Custom loops can be complex, making it difficult to reason about code behavior and establish post-conditions effectively. They are error-prone, particularly in scenarios where non-obvious conditions come into play, leading to potential vulnerabilities. Additionally, custom loops may inadvertently introduce performance bottlenecks, adversely affecting the application's responsiveness and efficiency. Lastly, they tend to complicate the surrounding code, increasing its complexity and making it less accessible for future developers.

```
for (auto const& b : buckets)
{
    if (b)
    {
        sum += b->getSize();
    }
}
...
bool
isZero(uint256 const& b)
{
    for (auto i : b)
        if (i != 0)
            return false;

    return true;
}
...
```

Recommendation

To address these concerns and uplift code quality, we recommend replacing custom loops with suitable STL algorithms. By embracing STL algorithms, you can streamline your codebase, enhance its readability, and mitigate the risk of introducing subtle bugs. Moreover, this transition ensures that your code adheres to C++ standards, fostering consistency and alignment with industry conventions. In conclusion, embracing STL algorithms is a prudent step toward improving code quality, making your codebase more maintainable, reliable, and efficient.

SHA256 Codebase

SHA256	Filename
0f7c5b47353ed36fbdf60b8620f13157132b9e6b7a9db96cb50cb11d26ca7b51	Makefile.am
b39727f870feb0f54b438abcba8d4c11fff8530b9ccbe5a35db08c3bcc325dd2	bucket/Bucket.cpp
6522c255ffd88ac1deff82137d83e64309b7d59d1823a38be38599aa8c341959	bucket/Bucket.h
e9d019278b3ebdd9017b5060cf6eb8e140a1c6ad636d89c1a46ef9c753ed1b2a	bucket/BucketApplicator.cpp
6fa3c1edfc271164365c0b13c9c049be1cc1868abd8a5f9396d23efa323d4dcd	bucket/BucketApplicator.h
935cb61d04449b8073e2a54da610e614b118c5e25220e249d2e5287f4437db31	bucket/BucketIndex.h
32820aa4cec1fd55afb74161f7b0e93fa553120e27f537008acfb96adec7d649	bucket/BucketIndexImpl.cpp
cae7a0238eb2d63bb7d670fc3561c43b65db62ed14321b7a7c02802b7f22d8f9	bucket/BucketIndexImpl.h
2cb8225d9c222bfcf6e24badced8bde23251812b29f4182d32a739210ab22534	bucket/BucketInputIterator.cpp
97cbf20ee96aabff757bc97b8a599b6df9b7cca4fa7a28e0f2edf42196f6d99d	bucket/BucketInputIterator.h
37ffa0f07059f1cd042d807ab94278e3089d855a51af9a1c607eea628afdf7b5	bucket/BucketList.cpp
197dfb3d524e3a25d0644b77c74a8799f90b49f560b5f2fdade51491eac6f358	bucket/BucketList.h
5637108ed6522264e49d4b2978c71a33f8ab8abc3221a81fe87f822e0821e548	bucket/BucketManager.h
35ad3484b803256223ed9b32d64645eef1691d955004966311cde4e9afb797e1	bucket/BucketManagerImpl.cpp
80861029a5c733e13bba8d5db606d730f93fb606809dbbcddf5266b2689752a3	bucket/BucketManagerImpl.h
4a3d460404fcc43e9dfbd91e7db411aea60d6bb9165a18e1f19e5d07fe975451	bucket/BucketMergeMap.cpp
5aa861a4b8cfa2ac7eb1e7af0e0742223b11657c6fb8a3d0222887294a943ac6	bucket/BucketMergeMap.h
3e8a0b0eff7e7499a9a0d15b62f03f23ef1dfa6bb0dc81d5ec8e6dc505b643f3	bucket/BucketOutputIterator.cpp
4ae54aef4b5ad10510fcd9d78fd6149c077643de8e86e39875d11996fe27f572	bucket/BucketOutputIterator.h
77c4d5ed4443c0efbe2b4ad675bfd5a7791799019a91e028b1b85893a7aa8a5e	bucket/FutureBucket.cpp
a0656b28a6d9d3240c4f95a96d59100747d8e4d618090ab59c99da13929ecd0a	bucket/FutureBucket.h
71349d6a5b26397e78a77cd6113a33388fd90fb441a23882ac4d38aac2659d6d	bucket/LedgerCmp.h
f8f5670227aa48b1372f389289c587933b579f05f2abc5db4e4dddfbc4e49398	bucket/MergeKey.cpp
4f8bccf1adb5a5b4be9a2229471b925da9b3b65daa469cbca290e0e0614598be	bucket/MergeKey.h
698fc009581c86c9b1966fa4017a424528f72d27ed087c9b9f11eb09ac009634	bucket/PublishQueueBuckets.cpp
4a6671e6275d578542fa834a74cf06986cdd1520f2757824a7c45e5f6d3229e3	bucket/PublishQueueBuckets.h
9e3bd7fb42c6d3c8453fa9e37e310c3429b30e52957bddf08a7d8a24f9502fee	bucket/readme.md
9304a868d1cda2be84919d927952b077dbfe38392c0152fb02acc6972b58f622	catchup/ApplyBucketsWork.cpp
6bdb3120d0aab6519c13bf1f5b3c2ac15119b7757fa7b90afffc0677149b51d3	catchup/ApplyBucketsWork.h
c0f7a237767290dbaffb133a4185745941cc5d3cbc8f063985eee2a33c719815	catchup/ApplyBufferedLedgersWork.cpp
af8b8750521d923557196e0fbb7d4bada22b555a9ae900827877116c0ea2ffbe	catchup/ApplyBufferedLedgersWork.h
9c83327d3aa4bf031316a76985b5970fc5d074dd802be45597c8c5f3293ea263	catchup/ApplyCheckpointWork.cpp
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ad15dbee09f72829565b334f5f39e21147be673ab67691a5625ace1f29035341	catchup/ApplyLedgerWork.cpp
d9370d9386d11ae7bc4c1cc33174b5fb2e738fa6cc065b4d4bc3e119759af7a9	catchup/ApplyLedgerWork.h
4cefc5f53bbd37fefec9432c7d945e527d649a85bf985035e65de83328e3f500	catchup/AssumeStateWork.cpp
c6999604ce134d4786ce699e49be8689164801b4f59aef082c0d891a803add22	catchup/AssumeStateWork.h
3a37524ee18cc2e7c094294ec07fc26f346e543e044bdbc5dd9a907613536e33	catchup/CatchupConfiguration.cpp
2601a26ac273fbb7fb61bcf27697edbf836e4343d42d80b6eaeb1d9a055e1922	catchup/CatchupConfiguration.h

ca8db4c6b47e99fd787aa3f503513194112117631ce1c9590ce8ce04ac826536	catchup/CatchupManager.h
7e4bd2d5e9a5521cee4a0acbc5cee431c596dffcec6259cd1b035c742a2bed37	catchup/CatchupManagerImpl.cpp
c334940d929d8a52fd0b1c606a6c71c6fbd2a64264455aed4352821f52d1ba70	catchup/CatchupManagerImpl.h
57abbd8e4044cedeb82e003e80e91577710497a798377c91220c73cd5adecce9	catchup/CatchupRange.cpp
4985e5ee93d0e2622e7f89c2575124a8b3c1f5483d300e762fe70253bbdc4e75	catchup/CatchupRange.h
a2ab329bfc67bfb33f8606f391f64b074681933db3fb4e5007aab00d74ca02ce	catchup/CatchupWork.cpp
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503863a8611ac7e3b06f44b681334ebc681f217cfd2472938a742a4978cf85ba	catchup/simulation/HistoryArchiveStream.cpp
4a9a9d64a197fc7ae86cc78aaf51802aa2e41f40e0138f436b50e5da721d29f9	catchup/simulation/HistoryArchiveStream.h
56accd09a2fb0ab091122b88e02edfd224ec1aabad341760770b28f5a258a9a3	catchup/simulation/TxSimApplyTransactionsWork.cpp
cd818038a65fb354e9e6ca8a7996ca08d22a6c01d17d970839ea533a3501515e	catchup/simulation/TxSimApplyTransactionsWork.h
57503909c7d643fdc64b4536738d074f79c4649e332cf1f9a93875c9afc90c72	crypto/BLAKE2.cpp
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0cdb6df7779be66bfa6cfec563ca735ae4224849610cf2e310b7c2821b608da9	crypto/Curve25519.cpp
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bd16317955b518226994309b5fa725dbed8c8ecccafe55ee2cb94733c7de38c4	crypto/ShortHash.cpp
2315917fb61002b4cc5c079e73e49c90c358ea5d1260daa67dc15e8a838c708d	crypto/ShortHash.h
636c1dee7a5ed3c8b4afcce35caf0e060990449795d5cc7424d536f25b659e35	crypto/SignerKey.cpp
155c10c867f0c9b7b47f306c7fe3b708188f2d8e6666cf8899323821b3ac3019	crypto/SignerKey.h
14dde9e734162d1b497a1113fee08beec64bde7611c3c58ee41e0d44ac00b8bd	crypto/SignerKeyUtils.cpp
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122d4fbcf88cffe3b37e0e5633192d9e3d6b7e24fb3c23a52fd2a193439b7579	crypto/StrKey.cpp
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6fef74cbd286e5a731a1c339b60edc956ecda0b8704005184bca318c7f775ce4	database/DatabaseConnectionString.cpp
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c581acfb91fd43d6dad35eca4bf38bb6e31f033d6f6dd1d2a6df7c6c66b659e5	herder/HerderSCPDriver.cpp
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c7677c967b9efc2ac65e2e20d05d87825ed5229d28020839a81a6507d8d1aa18	herder/LedgerCloseData.cpp
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48d8739abfe6005b25be99ae9c746b3a760fb087d2ceefec431d2b2f14461fee	herder/PendingEnvelopes.cpp
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8eddd3472a1cd75e30c3590e1bac61cbe21c26b297bd59d190aba0df5f5fe69c	herder/QuorumIntersectionChecker.h
a0086e372e70508f8923d8016fa354cfc9bf1cbf631b6ec21c6a541337134a7d	herder/QuorumIntersectionCheckerImpl.cpp
a4a0e87a9c1a99ca544ac84b41c55521cddb5c232789d2bf8d54364f70f44887	herder/QuorumIntersectionCheckerImpl.h
6cd75df115cb031cf023a64f32530edbb53879b9adef54e17b00b5ec9e5cf20b	herder/QuorumTracker.cpp
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ada12686fda3a7d6017da2113b2ab56235131dacd9917f35f6c92ea6d9cbcdc8	herder/SurgePricingUtils.cpp
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ad83f1c1279139a5277b096ca956c18cb637f1928a5e0dd4927434fc9db4f4ec	herder/TxSetFrame.cpp
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df521ce19fbcb2fecec18c0746044eae3e37dc7408a3d693ea1ca003489ca5de	herder/readme.md
971073bb270f5e585f4451bfcceb84b4c8116f0651e5e4fae9bae07ef9d0a4e3	herder/simulation/TxSimTxSetFrame.cpp
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d64eb4b4b466a6e2a4779fd408d383875d80a5fcc65dbde717a8f8f5cd117e3b	history/FileTransferInfo.cpp
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fb65e57fb2cb5143e87b7132e2b3903cd2dc194cd6a93ce30c2796f5cd3994ed	historywork/VerifyBucketWork.cpp
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e1d344d0190e2325885d350cae067fc214dffa83d9000fb23dd093b02b2fd3af	historywork/VerifyTxResultsWork.cpp
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8b47454909fdb179f825ba30bd046d784f40581d12a2d2542d3a2ebe0cfed622	historywork/WriteSnapshotWork.cpp
382c433eda0528321878661678f6ceae919db88850572acff7a29549a19b18f8	historywork/WriteSnapshotWork.h
c625aa62e846a3887ab4b3faaca6a7a48fa839486b36713b97a1358883e9143e	historywork/WriteVerifiedCheckpointHashesWork.cpp
da59e46f863808cbcb671860e07529f1ae3ef040356940b18fb0672cfc9da527	historywork/WriteVerifiedCheckpointHashesWork.h
a4ad4de5c3dc353d79e107912caaab3a460cb3cd45e60205bdf686d37e3ada30	invariant/AccountSubEntriesCountIsValid.cpp
fcc73720a0f9252c8c01827dd041eba91ca9fc4ef407ce730dde3afbee0d6142	invariant/AccountSubEntriesCountIsValid.h
35c42036c481fc5774b03010c72d2f73db1977a2cbc64357bf93c17385a4af78	invariant/BucketListIsConsistentWithDatabase.cpp
af3c27474df59efdd9b6eba71816c34fa9f2c4cf429fafda879a12749898fc15	invariant/BucketListIsConsistentWithDatabase.h
75c907b7183db46393ee965da62a30c3e72a315fa3767c63f774861d650fa283	invariant/ConservationOfLumens.cpp
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5fdb6e941b2562f68838113c23763818ab726b1287e20a1aa4dff96d54b196a7	invariant/InvariantDoesNotHold.h
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217a21cb606773965cfc51344eb7988e0e8c93a505af0d2744374fa211d3b2fd	invariant/SponsorshipCountIsValid.cpp
25a9d3cd9e3cd964a8c5e509570f9422df85a91f6999dddaf97bf78dd5796518	invariant/SponsorshipCountIsValid.h
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65c54307d45f301c65f5c283544f2d9dedede9cb8273f8d4b28d95af22f2f71e	ledger/FlushAndRotateMetaDebugWork.cpp
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927cc0348192537ac46d3325e38de0002c195fe92eee05acb01338003a7506f5	util/SpdlogTweaks.h
d1451fd97d95c3f9d692369cbd1a9f14cab7787c130c90de771e246ab9090382	util/StatusManager.cpp
2efb14a1a204f7e7b2f7d9fa2701990b890197ed7fb8481b4948c637ef5082dd	util/StatusManager.h
6c4c1b7a0734744b27a6dc79f50abaa6e01e4519b1c4cb808c934f41a3bcb039	util/TarjanSCCCalculator.cpp
a7be3b3896e2953cac6e29400f0612923d9fa38122249f09c6f93eb1a9595faa	util/TarjanSCCCalculator.h
163911b71ca69cfe2d11fd6b9b37a85c056ff7fd4d06617ff2c5541bfd60dc31	util/Thread.cpp
79674ec14e1404992771f9b76f20cfe949c224e4fa9c68483d2ffd802018af15	util/Thread.h
c4bff7fa02efd1ff857dc52245a47d73ea82d8afca626480ec533d832bb80e3f	util/Timer.cpp
b15c93907271357 53d64b88f42bb32c6e0bea17d1454c9d74ad9d641a050fc3a	util/Timer.h
a4d2f9c9d9ddef0ac4f391f9fee733cd7a3552bb32dae6927273f1a6f4d193b5	util/TmpDir.cpp
3da3b472f2b616b774c70d2e56ccede149e5e8b9e5d9b050a3d959e9b2acc298	util/TmpDir.h
9a2c5487019585a7221fec88978226f87ffa6fba8159da6acb5a5001379b8afd	util/TxResource.cpp
9f14ed01dab28109d415c1997748ef1f521fcd33ed9a71a452888bb4ef90a7b5	util/TxResource.h
505bf315461a5bf259e0f0b10edc05f2786ab7178bf21edb272c099a20abf6ad	util/UnorderedMap.h
c787ad546293e75c717ccf9da59b20e2fb4634e32eaac5d8d0c546c577a5ebc4	util/UnorderedSet.h
d03e40ae6a1c57a6940ea4ccb4d06ca3249f089de58615b7f6f62cdde623af54	util/XDRCereal.cpp
ff086751df806b72ecbf171cadb42945183e54cfaf29c0ad763fb78ef7d1add0	util/XDRCereal.h
b6ee50b686b8e4423a3702e934521d945b4c9bbdb029aeb8fd2eb5096f97413a	util/XDROperators.h
5a4b6ab35756364052edd44e11faa9d616a309c3336a1cdea1523088d14b3e6d	util/XDRStream.h

d2e8e30df72511af8abb19894a26b4ee297bee0dc510bcbde5866cfb9d24dc15	util/asio.h
5c6c477d442974ecb9b53b1e016eb5d9b3c254db314e79a109c18a04b5a154d5	util/must_use.h
2ad3e55c47c33312f8973aef029e6f228bb6b433122f7f6c4f3285ba0882077f	util/numeric.cpp
cbe56159abb192a82da95ace980624cee4f42163ca83e921ff1b036b26058bf8	util/numeric.h
f50ec7737e11a2a0aaf6d2ec08a2f57007d8e2e47807e22de6925ab97c75c82c	util/numeric128.h
7a2d5b4a82659e45466839975872ef643643254b028579238c4282ee8a8531bf	util/types.cpp
78652aa3e62aa1719b3f2ac992d57317df10cb8294ce896bf6e88a737bb51a4d	util/types.h
94da1ff4cf100c1919d528edf69f97958cc05371c782382c1b1f12132b9d7cb4	util/xdrquery/XDRFieldResolver.h
8a0c7d323cce7bb0c6f54cef9c4bc042fd7ff840291daf9ff6ae888e4bf98616	util/xdrquery/XDRQuery.cpp
020d1cb08f40447931c6b14d1df6fa7b4df14da3371d40039e6ecd8c8ab6f557	util/xdrquery/XDRQuery.h
f5348464b85cd30bbc874aa3319118ac4f6f6ae6aa6c9a9de3f2996b18b52ac8	util/xdrquery/XDRQueryError.h
9134a87c529e2c2d87e7e1ef03c733ce2e996c98e49690de7455851acadad4ac	util/xdrquery/XDRQueryEval.cpp
b18e958d2b97a9b6c1246cd19436496acf80f869823589eacedf4f3dde6a539d	util/xdrquery/XDRQueryEval.h
62b643752b6d8a2f699d94f11bebbe665a6cbbb8fd68d10397a60c3e1ae00ebb	util/xdrquery/XDRQueryParser.yy
b0d7ac770adcc4e2d637b36b2fb8a68f509ae9b9d89b5e3d7ed618b4ab9ba260	util/xdrquery/XDRQueryScanner.ll
525820f519d8839c074cfc717117ed3109d525f62d3f8455a7ec2cd9d096bbfe	work/BasicWork.cpp
7ff4e708e36185e0dc9384af5a9defc10834c5536fcc6e9fb2a0c58d9d61f0e7	work/BasicWork.h
a18a8ba07bbf1073499761367698bbaff2c63be0d2bacd7b0dd6edbd6bbd762d	work/BatchWork.cpp
a6652bb423223adf917fc094177eb7df31851d7feaf9401ff5e534d4da552da8	work/BatchWork.h
c37683eaf6154477445d8845e1ac33ecef66aaea9283ca718d55e8e7e32ec0d7	work/ConditionalWork.cpp
21187b2e50a8bf29be4e072d50438bc3a545bee4198ce8708536fbdcdafe0871	work/ConditionalWork.h
b83ea990b317d14aa055a857682dbf337c127d618b2f5dd84e4c103ef4cc0785	work/Work.cpp
7a1e2589bcdd2adb2cf4342149e1eaeeef374355879e19e0884a2d094d0036ed	work/Work.h
db4b68ec8286af16adce8f3234603a93398d017940da3ffdb3269850570e41ba	work/WorkScheduler.cpp
ee1eb97e0d80744cb416329f754a2af24319d23e34867a4e7b395f73bfd64745	work/WorkScheduler.h
fe6c0463101f1f7b85ee5dfdd47841dee3f57a3c18644352c8bad2ff6f71393c	work/WorkSequence.cpp
c613f94426dc8c433f1f6f2992881a37c1bd43210d4d7d1ebaf3fe7f21e26a03	work/WorkSequence.h
a2648a083d6d50a9e94e7ca966c3c1161811868ae4607b0b275e465633df1ac0	work/WorkWithCallback.cpp
6f7f66a8770167ad16864fd8678a0782c461f161f4e230e574b95e3e8af22982	work/WorkWithCallback.h

Summary

Overall, Elar's codebase exhibits a well-designed and organized architecture that prioritizes efficiency, security, and maintainability. Its adherence to the Stellar Consensus Protocol, modular design, and efficient ledger management contribute to its robustness and reliability in maintaining a distributed cryptographic ledger. This audit provides confidence in the system's ability to fulfill its role in the Stellar ecosystem. The code review and auditing process have uncovered several key areas for improvement within the C++ codebase.

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