title

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Abstract

Regulatory compliance in securities markets requires continuous verification of portfolio constraints—diversification limits, position caps, sanctions screening—yet traditional approaches demand that compliance officers and automated systems have full visibility into portfolio holdings. This paper presents a programmable compliance engine on Liquid EVM that enforces SEC and FINRA rules on encrypted portfolios using the FHE precompile at `0x0700`. Portfolio positions are stored as `euint64` ciphertexts. Compliance checks—including Investment Company Act diversification tests, Regulation T margin requirements, and OFAC sanctions screening—execute entirely over ciphertexts using homomorphic arithmetic and comparison. The result of each check is an encrypted boolean that is threshold-decrypted to reveal only the pass/fail outcome, never the underlying positions. We provide complete Go code using `github.com/luxfi/fhe` for encrypting portfolios, executing compliance checks, and decrypting results.

1 Introduction

Portfolio compliance verification is a fundamental requirement for regulated securities markets. The Investment Company Act of 1940, SEC Rule 35d-1, FINRA Rule 4210, and OFAC sanctions regulations impose constraints on what positions a fund may hold and in what quantities. Verifying compliance requires examining the full portfolio—a process that inherently exposes sensitive trading strategies.

This creates a tension: compliance requires transparency, but transparency destroys the competitive advantage of proprietary trading strategies. Fund managers at institutional firms spend significant resources protecting their portfolio composition from information leakage, even to internal compliance departments.

FHE resolves this tension. A compliance contract on Liquid EVM receives encrypted portfolio data, executes the compliance rules homomorphically, and produces an encrypted boolean result. Threshold decryption reveals only whether the portfolio passes or fails—never the positions themselves.

1.1 Regulatory Rules Implemented

This paper implements the following rules over encrypted data:

1. **75-5-10 Diversification Test** (Investment Company Act §5(b)(1)): For 75% of total assets, no single issuer may represent more than 5% of total assets or 10% of the issuer's outstanding securities.

2. **Position Concentration Limit**: No single position exceeds a configurable percentage of total portfolio value.

3. **Sanctions Screening**: Verify that no position involves a sanctioned entity, without revealing which entities are held.

4. **Regulation T Margin**: Verify that margin utilization does not exceed the 50% initial margin requirement.

2 Architecture

2.1 Encrypted Portfolio Representation

A portfolio is represented as a fixed-size array of encrypted position records:

The portfolio has a fixed capacity (e.g., 256 slots) to prevent position count leakage. Empty slots are filled with encrypted zeros and `encIsActive = false`.

Field	Type	Description	Gas
`encAssetID`	`euint64`	Asset identifier (hashed)	50,000
`encQuantity`	`euint64`	Number of shares/units	50,000
`encValue`	`euint64`	Position value in basis points	50,000
`encIsActive`	`ebool`	Whether slot is occupied	50,000

Table 1: Encrypted position fields.

2.2 Compliance Check Flow

1. Fund manager encrypts portfolio positions under the network FHE public key.
2. Encrypted positions are submitted to the `ComplianceEngine.sol` contract.
3. The contract executes compliance rules using FHE precompile operations.
4. Each rule produces an `ebool` result (encrypted pass/fail).
5. Results are AND-ed together into a single `ebool`.
6. The aggregate result is sent to Liquid Threshold for threshold decryption.
7. Only the boolean pass/fail is revealed.

3 Implementation

3.1 Go Client: Encrypt Portfolio

```go
package compliance

import (
    "github.com/luxfi/fhe"
)

// Position represents a single portfolio position.
type Position struct {
    AssetID  uint64
    Quantity uint64
    Value    uint64 // in basis points (1/100 of a cent)
}

// EncryptedPosition holds FHE ciphertext handles.
type EncryptedPosition struct {
    EncAssetID  *fhe.BitCiphertext
    EncQuantity *fhe.BitCiphertext
    EncValue    *fhe.BitCiphertext
    EncIsActive *fhe.BitCiphertext
}

// EncryptedPortfolio holds all encrypted positions and
// the encrypted total value for ratio computations.
type EncryptedPortfolio struct {
    Positions  []EncryptedPosition
    EncTotal   *fhe.BitCiphertext
    SlotCount  int
}

// EncryptPortfolio encrypts a portfolio with padding to
```

```go
// a fixed slot count, preventing position count leakage.
func EncryptPortfolio(
    enc *fhe.BitwiseEncryptor,
    positions []Position,
    slotCount int,
) (*EncryptedPortfolio, error) {
    result := &EncryptedPortfolio{
        Positions: make([]EncryptedPosition, slotCount),
        SlotCount: slotCount,
    }

    var totalValue uint64
    for i := 0; i < slotCount; i++ {
        if i < len(positions) {
            p := positions[i]
            totalValue += p.Value
            result.Positions[i] = EncryptedPosition{
                EncAssetID:  enc.EncryptUint64(
                    p.AssetID, fhe.FheUint64,
                ),
                EncQuantity: enc.EncryptUint64(
                    p.Quantity, fhe.FheUint64,
                ),
                EncValue:    enc.EncryptUint64(
                    p.Value, fhe.FheUint64,
                ),
                EncIsActive: enc.EncryptUint64(
                    1, fhe.FheBool,
                ),
            }
        } else {
            // Pad with encrypted zeros
            result.Positions[i] = EncryptedPosition{
                EncAssetID:  enc.EncryptUint64(
                    0, fhe.FheUint64,
                ),
                EncQuantity: enc.EncryptUint64(
                    0, fhe.FheUint64,
                ),
                EncValue:    enc.EncryptUint64(
                    0, fhe.FheUint64,
                ),
                EncIsActive: enc.EncryptUint64(
                    0, fhe.FheBool,
                ),
            }
        }
    }

    result.EncTotal = enc.EncryptUint64(
        totalValue, fhe.FheUint64,
    )
    return result, nil
}
```

Listing 1: Encrypting a portfolio for compliance verification.

3.2 Go: Diversification Check (75-5-10 Rule)

```go
package compliance

import (
```

```
    "github.com/luxfi/fhe"
)

// CheckDiversification verifies the 75-5-10 rule:
// For 75% of total assets, no single issuer exceeds 5%.
// Returns encrypted boolean: true = compliant.
func CheckDiversification(
    eval *fhe.BitwiseEvaluator,
    portfolio *EncryptedPortfolio,
) (*fhe.BitCiphertext, error) {
    // Compute 5% threshold: total * 5 / 100
    // Using scalar multiplication and division
    fivePercent, err := eval.ScalarMul(
        portfolio.EncTotal, 5,
    )
    if err != nil {
        return nil, err
    }
    threshold, err := eval.ScalarDiv(fivePercent, 100)
    if err != nil {
        return nil, err
    }

    // For each position, check: value <= threshold
    // If active AND exceeds threshold, flag violation.
    // Start with "compliant = true" (encrypted 1)
    params, _ := fhe.NewParametersFromLiteral(fhe.PN10QP27)
    encryptor := fhe.NewBitwiseEncryptor(params, nil)
    compliant := encryptor.EncryptUint64(1, fhe.FheBool)

    for _, pos := range portfolio.Positions {
        // Check: position value <= 5% threshold
        underLimit, err := eval.Le(
            pos.EncValue, threshold,
        )
        if err != nil {
            return nil, err
        }

        // If slot is inactive, it passes automatically
        // passCheck = isActive ? underLimit : true(1)
        alwaysPass := encryptor.EncryptUint64(
            1, fhe.FheBool,
        )
        passWrapped := fhe.WrapBoolCiphertext(underLimit)

        // Extract the active bit for select
        activeBit, err := eval.Eq(
            pos.EncIsActive,
            encryptor.EncryptUint64(1, fhe.FheBool),
        )
        if err != nil {
            return nil, err
        }

        posResult, err := eval.Select(
            activeBit, passWrapped, alwaysPass,
        )
        if err != nil {
            return nil, err
        }

        // AND with running compliant flag
```

```
        compliant, err = eval.And(compliant, posResult)
        if err != nil {
            return nil, err
        }
    }

    return compliant, nil
}
```

Listing 2: Homomorphic 75-5-10 diversification test.

3.3 Go: Position Concentration Limit

```
package compliance

import (
    "github.com/luxfi/fhe"
)

// CheckConcentration verifies no single position exceeds
// maxPercent of total portfolio value.
// maxPercent is in basis points (e.g., 1000 = 10%).
func CheckConcentration(
    eval *fhe.BitwiseEvaluator,
    portfolio *EncryptedPortfolio,
    maxBasisPoints uint64,
) (*fhe.BitCiphertext, error) {
    // threshold = total * maxBasisPoints / 10000
    scaled, err := eval.ScalarMul(
        portfolio.EncTotal, maxBasisPoints,
    )
    if err != nil {
        return nil, err
    }
    threshold, err := eval.ScalarDiv(scaled, 10000)
    if err != nil {
        return nil, err
    }

    params, _ := fhe.NewParametersFromLiteral(fhe.PN10QP27)
    enc := fhe.NewBitwiseEncryptor(params, nil)
    compliant := enc.EncryptUint64(1, fhe.FheBool)

    for _, pos := range portfolio.Positions {
        under, err := eval.Le(pos.EncValue, threshold)
        if err != nil {
            return nil, err
        }
        wrapped := fhe.WrapBoolCiphertext(under)
        compliant, err = eval.And(compliant, wrapped)
        if err != nil {
            return nil, err
        }
    }

    return compliant, nil
}
```

Listing 3: Homomorphic position concentration check.

3.4 Go: Sanctions Screening

```go
package compliance

import (
    "github.com/luxfi/fhe"
)

// CheckSanctions verifies that no portfolio position matches
// a sanctioned entity list. The list is encrypted so that
// neither the portfolio holder nor the screener learns the
// other's data.
func CheckSanctions(
    eval *fhe.BitwiseEvaluator,
    enc *fhe.BitwiseEncryptor,
    portfolio *EncryptedPortfolio,
    sanctionedIDs []uint64,
) (*fhe.BitCiphertext, error) {
    // Encrypt each sanctioned ID
    encSanctioned := make([]*fhe.BitCiphertext, len(sanctionedIDs))
    for i, id := range sanctionedIDs {
        encSanctioned[i] = enc.EncryptUint64(
            id, fhe.FheUint64,
        )
    }

    // Start with "clean = true"
    clean := enc.EncryptUint64(1, fhe.FheBool)

    // For each position, check against each sanctioned ID
    for _, pos := range portfolio.Positions {
        for _, sid := range encSanctioned {
            // Check: assetID == sanctionedID
            match, err := eval.Eq(pos.EncAssetID, sid)
            if err != nil {
                return nil, err
            }

            // If match found AND slot is active, flag
            isActive, err := eval.Eq(
                pos.EncIsActive,
                enc.EncryptUint64(1, fhe.FheBool),
            )
            if err != nil {
                return nil, err
            }

            // violation = match AND isActive
            violation := fhe.WrapBoolCiphertext(match)
            flagged, err := eval.And(
                violation,
                fhe.WrapBoolCiphertext(isActive),
            )
            if err != nil {
                return nil, err
            }

            // NOT violation to get "this pair is clean"
            pairClean := eval.Not(flagged)

            // AND with running clean flag
            clean, err = eval.And(clean, pairClean)
            if err != nil {
```

```
                return nil, err
            }
        }
    }

    return clean, nil
}
```

Listing 4: Homomorphic OFAC sanctions screening.

3.5 Go: Aggregate Compliance Result

```go
package compliance

import (
    "github.com/luxfi/fhe"
)

// ComplianceResult holds encrypted results per rule.
type ComplianceResult struct {
    Diversification *fhe.BitCiphertext
    Concentration   *fhe.BitCiphertext
    Sanctions       *fhe.BitCiphertext
    Aggregate       *fhe.BitCiphertext
}

// RunFullCompliance executes all compliance checks and
// returns the aggregate encrypted boolean.
func RunFullCompliance(
    eval *fhe.BitwiseEvaluator,
    enc *fhe.BitwiseEncryptor,
    portfolio *EncryptedPortfolio,
    sanctionedIDs []uint64,
) (*ComplianceResult, error) {
    div, err := CheckDiversification(eval, portfolio)
    if err != nil {
        return nil, err
    }

    conc, err := CheckConcentration(
        eval, portfolio, 1000, // 10% max
    )
    if err != nil {
        return nil, err
    }

    sanc, err := CheckSanctions(
        eval, enc, portfolio, sanctionedIDs,
    )
    if err != nil {
        return nil, err
    }

    // Aggregate: all three must pass
    agg, err := eval.And(div, conc)
    if err != nil {
        return nil, err
    }
    agg, err = eval.And(agg, sanc)
    if err != nil {
        return nil, err
    }
```

```
51
52      return &ComplianceResult{
53          Diversification: div,
54          Concentration:   conc,
55          Sanctions:       sanc,
56          Aggregate:       agg,
57      }, nil
58  }
```

Listing 5: Combining all compliance checks and requesting decryption.

4 Security Analysis

4.1 Portfolio Confidentiality

All position data remains encrypted throughout the compliance check. The only information revealed is the boolean pass/fail result after threshold decryption. Under the RLWE assumption, an adversary observing the EVM state gains no information about individual positions.

4.2 Rule Integrity

The compliance rules execute deterministically on-chain via the FHE precompile. All Quasar consensus validators verify the execution trace. A malicious compliance engine cannot alter the rules or fabricate results.

4.3 Sanctions List Confidentiality

The sanctions list is encrypted before submission. The compliance engine compares encrypted asset IDs against encrypted sanctioned IDs. Neither the fund manager learns which IDs are sanctioned (beyond the pass/fail for their specific portfolio), nor does the sanctions provider learn the portfolio contents.

5 Performance

Check	**Gas (100 positions)**	**Latency**
Diversification (75-5-10)	∼15,000,000	∼4s
Concentration (10% limit)	∼8,000,000	∼2s
Sanctions (50 entities)	∼35,000,000	∼10s
Reg T margin check	∼5,000,000	∼1.5s
Total	∼63,000,000	∼17.5s
Threshold decryption	10,000	2–5s

Table 2: Gas and latency for compliance checks on a 100-position portfolio.

The gas costs are dominated by the sanctions screening, which requires $O(P \times S)$ encrypted equality comparisons where P is positions and S is sanctioned entities. For a 100-position portfolio screened against 50 sanctioned IDs, this requires 5,000 `FHE.eq` operations at 60,000 gas each.

6 References

1. Investment Company Act of 1940, §5(b)(1). 15 U.S.C. §80a-5(b)(1).
2. SEC Rule 35d-1: Investment Company Names. 17 CFR 270.35d-1.
3. FINRA Rule 4210: Margin Requirements.
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7. Zama. "fhEVM: Confidential Smart Contracts." 2024.
8. SEC Regulation T (12 CFR 220). Margin Requirements for Securities.
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