Boundary Flow Modeling (BFM)

Security Policy, Architecture, and Behavior Modeling for Distributed Systems

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The Message

Boundary Flow Modeling describes security characteristics in terms of data flow histories at element boundaries.

We have shown this method to be effective for distributed systems.
Contents

• Boundary Flow Modeling, Briefly
• Some Identified Security Modeling Needs + Characteristics of a Solution
• BFM Methods and Examples
• How BFM Meets the Identified Needs
• Current BFM Evolutionary Developments
BFM, Briefly

• Characteristics that BFM models
  – Policy (security requirements)
  – Architecture (high level design)
  – Behavior of elements (system, subsystems, components), viewed as black boxes

• The key of understanding BFM
  – The “words” in the modeling “language” are:
    histories of data flows
    across external interfaces of elements
  – The “sentences” are:
    logical relationships among histories
  – The “stories” are: inferences among relationships
Identified Security Modeling Needs

• Primary need: Modeling policy, architecture, and behavior of distributed systems

• Related need: Addressing the security composition problem

• Solution characteristics—a solution would have to:
  – Provide a black box view of individual targets.
  – Provide an alternative to state modeling—models need to be in terms of external boundaries.

• We propose that BFM is such a solution.
Detailing the BFM Process

• Define an example:
  Data Sorter, a simple (distributed) system

• Walk through the process:
  Perform the steps of the process on the example.

• Identify “real” examples:
  Systems we addressed with BFM
The Process

A Simple Example: Data Sorter

```
System
  Splitter
    Classified Sender
    Unclassified Sender
      Classified Data Sink
      Unclassified Data Sink
```

Data Source
The Process
Diagram of Phases

Phase 1
Security Architecture Structure Modeling...

Phase 2
...Enhanced by Information Flow...

Phases 3 & 4
...with Chain-of-Logic Assertion Dependencies
The Process

Phase Details

• *Phase 1*: Express the architecture
  Elements and component relationships

• *Phase 2*: Interfaces and data flows
  Expressed in terms of histories at interfaces

• *Phase 3*: Security constraints/behavior
  Expressed as relationships among histories

• *Phase 4*: Inferences among relationships
  Element assumptions in terms of assertions of
  component and peer elements

• *Phase 5*: Chain of Logic
  Applying *modus ponens* to the inferences:
  Validating system policy from leaf elements
The Process

“Real” Examples—Actual Systems

• Multinet Gateway and network environment
  – MLS network gateway (RADC and NSA)—1985-1990

• File Server example
  – Formal design modeling to validate Gypsy environment
    (Current Endorsed Tools List Example—
     National Computer Security Center (NCSC)—1991)

• F-22A Weapon System architecture and platforms

• Joint Simulation System (JSIMS): Warfighter Training System
  – Two-enclave modeling and simulation system
    (joint sponsorship—1999-2001)
Does BFM Meet the Identified Needs?

• Solution characteristics
  – Statement: black box view of element modeling
  – Statement: modeling in terms of interfaces, not state
  – Conclusion: BFM has these characteristics

• Primary need
  – BFM models policy, architecture, and behavior of elements.
  – BFM is appropriate for distributed systems.
    (permits nondeterminism)

• Related need
  – BFM approach addresses the composition problem.
A Statement of the Security Composition Problem

If you have two components, each with a security policy, what is the policy enforced (if any) when the two components are combined?

- Policy based on combined state,
- System is distributed, has no state

System A+B

Component A

Component B

Policy A

Policy B
Making Sense of Security Composition

MAC+DAC

System FlowCtrl

Component MACfilter

Component DACfilter

FH1

FH2

FH3

MAC

DAC

Source

Destination

Enforces MAC Rules

Enforces DAC Rules
Composition Example Policies in BFM

- **MAC** Policy:
  Every packet in \( FH2 \) has the same content as a packet in \( FH1 \) with the MAC rules satisfied.

- **DAC** Policy:
  Every packet in \( FH3 \) has the same content as a packet in \( FH2 \) with the DAC rules satisfied.

- **MAC+DAC** Policy:
  Every packet in \( FH3 \) has the same content as a packet in \( FH1 \) with both the DAC rules and the MAC rules satisfied.

- To demonstrate based on system architecture:
  **MAC** Policy AND **DAC** Policy IMPLIES **MAC+DAC** Policy
Current BFM Evolutionary Development

• Soundness of flow history relationships
  – Issue of logical soundness of flow history relationships for separated elements

• Integrating BFM and state models
  – Value and approach of model integration within distributed systems

• Tool support for BFM
  – Need, past attempts, and plans
Soundness of Flow History Relationships

• The Pitfall
  – It’s easy to end up with unsound statements.
  – Key issue: inadvertent assumption of a system-wide time referent—not a problem with “local” elements
  – Past use of “oracle functions” has defied detailed definition:
    For every entity $e_2$ in $H_2$
    there is an entity $e_1$ in $H_1$
    such that $e_1 = e_2$
    (This ignores that $e_1$ may have appeared after $e_2$, while we are trying to make $e_1$ account for $e_2$!)
  – We can stay with a “mushy” definition of Derived_From, but that defeats any but the most minimal assurance.
Soundness of Flow History Relationships (2)

- The Plan—supporting diagram
Soundness of Flow History Relationships (3)

• The Plan
  – Elaborate Derived_From based on a “local” element function Derived_From_Local.
  – This new function is applicable only to architecturally local elements, within which time is definable.
  – Derived_From_Local time orders all history entities appearing at its external interfaces.
  – Given the local time ordering, by which history entities have been locally time stamped, Derived_From associated with higher level elements (containing the related local elements) can express sound accountability relationships.
  – Remaining question: when can a communications channel be considered a local element?
Integrating BFM and State Models

• The Issue
  – Some (local) elements are best modeled using a state approach.
  – But distributed systems and subsystems need to be modeled using BFM.
  – Therefore, for a complete system security integration, the two modeling schemes must be coordinated.
Integrating BFM and State Models (2)

• The Status and Plan
  – A successful experiment:
    • Restating the GWV (state-based policy) of a separation kernel (SK) in BFM
    • Demonstrating that the BFM statement of the policy is true whenever the GWV statement of the policy is true
    • Result: The BFM scheme can validly use the claim of BFM form of the SK policy to contribute to inferring the policy of an element that contains the SK.
  – To be done
    • Perform similar experiments in other contexts (e.g., the state model of an entire platform).
    • Obtain community review of these experiments.
Tool Support for BFM

• The Need
  – Efficiency in the modeling process
  – Presentation of the model to developers, reviewers, and customers
  – Accurate validation of the model
Tool Support for BFM (2)

• The Accomplishments
  – Developed an XML-based tool.
  – The tool:
    • Accurately represents the model.
    • Allows (more-or-less) convenient capturing of model data.
    • Supports model validation.
    • Supports (marginal) graphical presentation of the model.
  – Applied the tool to a number of modeling tasks.

• Plan
  – Assess commercial tools (most are based on UML) for feasibility of add-ons to support BFM process needs.
  – Implement the add-ons and apply to modeling tasks.
CONCLUSIONS

• BFM is a feasible modeling scheme.
• BFM is workable in a number of contexts.
• BFM can be integrated with other modeling schemes.
• Claim: With adequate tool support, BFM can be used to provide necessary security assurance within production system development.