Transition Systems and Invariants

EECS 755—Software Systems Modeling

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Presentation Outline

- Review access control modeling objectives
  - modeling platform MAC
  - modeling local access control
- Overview access control policy definition
  - design and modeling assumptions
  - platform boot policy definition
  - local policy definitions
- Overview models
  - domain and system models
  - communication model
  - theorems and status
- Identify next steps
  - runtime and moving beyond the SVP line
  - adding M&A detail

KU INFORMATION AND TELECOMMUNICATION TECHNOLOGY CENTER
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Access Control Modeling Objectives

What we're about here

Reporting joint work with Geoffrey Brown, Indiana University (submitted) in which we verify two physical layer protocols.

- Biphase Mark Protocol (BMP)
- 8N1 Protocol

These protocols are used in data transmission for CDs, Ethernet, and Tokenring, etc. as well as UARTs.

- Correctness is reasonably difficult to prove due to many real-time constraints.
- Many previous formal modeling/verification efforts for these protocols.

Columns and Blocks

Trying figures next to lists

Some normal text goes here just for introduction

- Appraisal
- Measurement
- Attestation
- vTPM

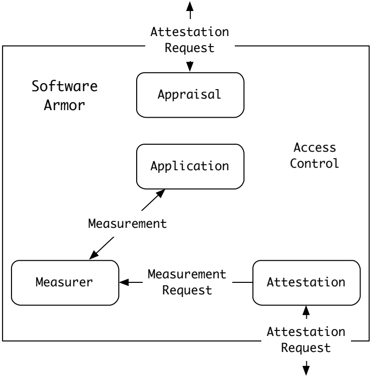
Why is this column getting higher?

Maybe it's not

Center alignment seems best.

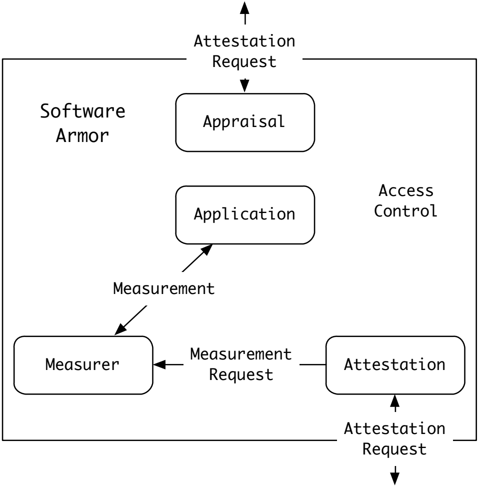
I like this for two column test and graphics

Getting higher???



Big Picture

Armor Architecture



Simple Block

Introduction to LaTeX

“Beamer is a LaTeXclass for creating presentations that are held using a projector...”

This is a definition

Proofs

Not really a proof.

1. This is a step

□

Proofs

Not really a proof.

1. This is a step
2. This is another step

□

Proofs

Not really a proof.

1. This is a step
2. This is another step
3. This is a third step
4. This is a third step
5. This is a third step
6. This is a third step

□

List with Overlays

- Item 1 followed by a pause

List with Overlays

- Item 1 followed by a pause
- Item 3 followed by a pause

List with Overlays

- Item 1 followed by a pause
- Item 2 followed by a pause
- Item 3 followed by a pause

Previous Efforts

- BMP has been verified in PVS twice and required
  - 37 invariants and 4000 individual proof directives (initially) in the one effort
  - 5 hours just to *check* the proofs in the other effort
  - A formal specification and verification of an independent real-time model in both efforts
- BMP has been verified in (the precursor to) ACL2 by J. Moore and required
  - A significant conceptual effort to fit the problem in the logic, arguably omitting some salient features of the model
  - The statement and proof of many antecedent results
  - J. Moore reports this as one of his “best ideas” in his career

Not Your Father's Theorem-Prover

The verifications are carried out in the SAL infinite-state bounded model-checker that combines SAT-solving and SMT decision procedures to *prove* safety properties about infinite-state models.

- Theorem-proving efforts took multiple engineer-months if not years to complete.
- Our initial effort in SAL consumed about *two engineer-days*. ...and we found a significant bug in a UART application note.

Parameterized Timing Constraints

SMT allows for *parameterized* proofs of correctness. The following are example constaints from the BMP verification:

```
TIME: TYPE = REAL;

TPERIOD: TIME = 16;
TSAMPLE: INTEGER = 23;

TSETTLE: {x: TIME |     0 <= x
                    AND (x + TPERIOD < TSAMPLE)
                    AND (x + TSAMPLE + 1 < 2 * TPERIOD)};

TSTABLE: TIME = TPERIOD - TSETTLE;

ERROR: {x: TIME |     (0 <= x)
                  AND (TPERIOD + TSETTLE < TSAMPLE*(1-x))
                  AND (TSAMPLE*(1+x) + (1+x) + TSETTLE < 2 * TPERIOD)};

RSAMPMAX: TIME = TSAMPLE * (1 + ERROR);
RSAMPMIN: TIME = TSAMPLE * (1 - ERROR);
RSCANMAX: TIME = 1 + ERROR;
RSCANMIN: TIME = 1 - ERROR;
```

SRI's SAL Toolset

- Parser
- Simulator
- Symbolic model-checker (BDDs)
- Witness symbolic model-checker
- Bounded model-checker
- Infinite-state bounded model-checker
- Future releases include:
  - Explicit-state model-checker
  - MDD-based symbolic model-checking

All of which are "state-of-the-art"

k-Induction

Please direct your attention to the whiteboard.

Timeout Automata[1] (Semantics)

An *explicit* real-time model.

- Vocabulary:
  - A set of state variables.
  - A *global clock*, $c \in \mathbb{R}^{0\leq}$.
  - A set of *timeout* variables T such that for $t \in T$, $t \in \mathbb{R}^{0\leq}$.
- Construct a transition system $\langle S, S^0, \rightarrow \rangle$:
  - States are mappings of all variables to values.
  - Transitions are either *time transitions* or *discrete transitions*.
    - Time transitions are enabled if the clock is less than all timeouts. Updates clock to least timeout.
    - Discrete transitions are enabled if the clock equals some timeout. Updates state variables and timeouts.

[1] B. Dutertre and M. Sorea. Timed systems in SAL. *SRI TR*, 2004.

Disjunctive Invariants

Even with *k*-induction, getting a sufficiently strong invariant is still hard! *Disjunctive invariants* help. A disjunctive invariant can be built iteratively from the counterexamples returned for the hypothesized invariant being verified.

```
t0:  THEOREM system |-
       G(   (    (phase = Settle)
             AND (rstate = tstate + 1)
             AND (rclk - tclk - TPERIOD > 0)
             AND (tclk + TPERIOD + TSTABLE - rclk > 0))
         OR
            (    (phase = Stable)
             AND (rstate = tstate + 1)
             AND (rclk - tclk - TSETTLE > 0)
             AND (tclk + TPERIOD - rclk > 0)
             AND (rdata = tdata))

                      .
                      .
                      .
```