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Towards Run-time Verification in Access Control

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Motivation

- How can we exploit existing software model checking tools that
  - Allow mimicking RBAC run-time
  - Support finite/infinite state analysis

- What concepts/techniques can be borrowed from run-time verification[1]?

1: http://en.wikipedia.org/wiki/Runtime_verification

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Desired properties

- Mutually Exclusive Roles (MER)
  - e.g. accountant vs. auditor
- Separation of Duty (SoD)
  - e.g. two signatures required for payment over $5K
  - even static version is co-NP
  - simulate with MER
- Conflict of Interest (CoI)
  - e.g. applicant vs. reviewer
- All require run-time verification

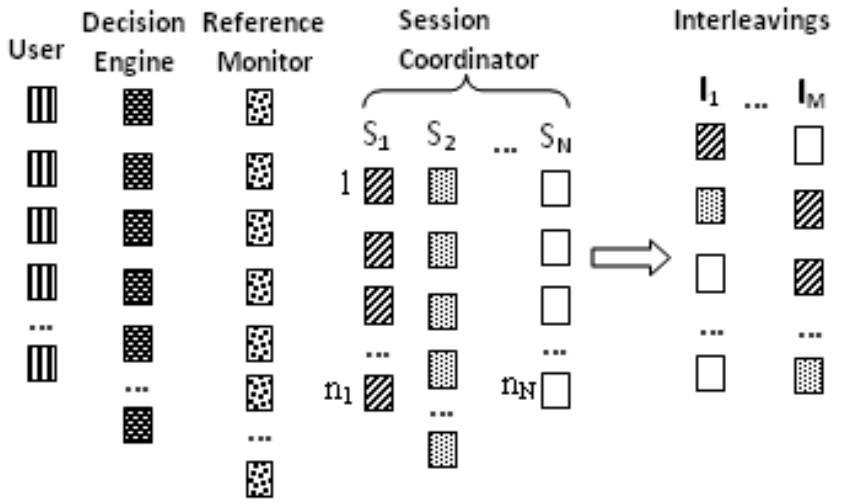
Example policy

- Alice is a senior accountant and Bob is a junior accountant at Firm Fermata.
- An accountant can view and edit his or her clients' information.
- An accountant can audit his or her junior accountants' edits.
- A junior accountant covers for the senior accountant when the senior is out of office.

Static vs. Dynamic verification

- Dynamic verification
  - benefit from all the run-time information
    - e.g. user name, activated roles, session information, …
  - imposes overhead on the system
    - coordination and synchronization over distributed systems is costly
- Static verification
  - can use more resource and time
  - lacks the run-time information

State Explosion



$$M = \frac{(\sum_{i=1}^{N} n_i)!}{\prod_{i=1}^{N} (n_i!)}$$

- Each session runs in its own thread
- Atomic operations are authorization events (A_R, D_R and A_P)

- Exponential combination of session interleavings
- Also for all possible values of dynamic info

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Static approximates Dynamic

- Our idea
  - static approximation of run-time verification
  - via simulating dynamic simultaneous sessions
  - similar to approaches in software verification
- Current status
  - given the policy, simulate roles and users
  - adopted simple temporal properties to simulate events
  - can verify dynamic Mutually Exclusive Roles
    - thus approximates dynamic Separation of Duty

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Scala Actor Framework

- Event-based
  - role (de-)activation, permission request: all events
  - scales well with many actors
- Thread-based
  - send/receive requests for role and permission activation
- Our approach: access control policy is modeled in Scala Actor Framework and treated as "software" that needs verification

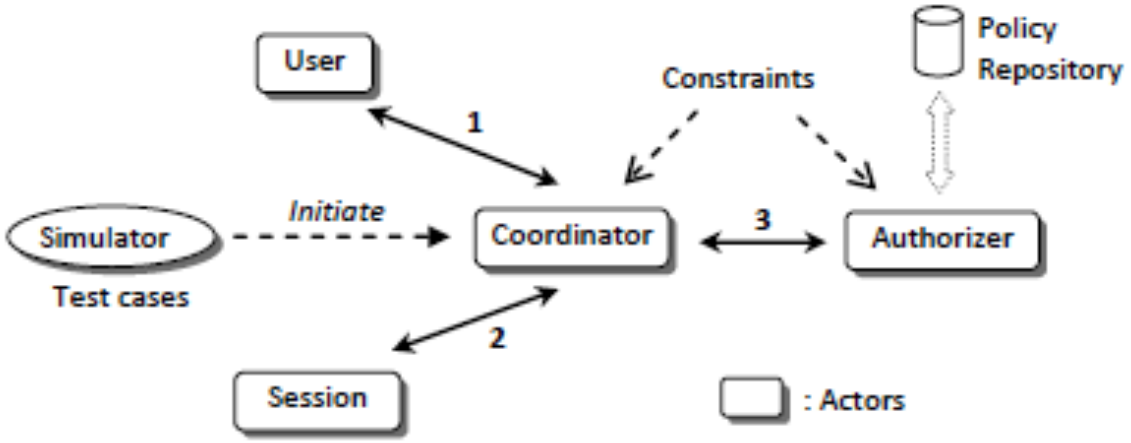
Example codes

```
Coordinator
def act(){
  authorizer.start
  var authActorClose: Int = 0
  while(true){
    receive{
case s : Session =>
   requestCount(s.getUser.getUserID)
   if user is allowed more sessions
s.getUser.addSession
s.getUser ! SessionPositive
   } else {
s.getUser ! SessionNegative
authActorClose = authActorClose + 1
   if (authActorClose == userNum){
authorizer ! Stop
exit()
   }
   }
case event : PA =>
   authorizer ! event
   receive{
      case Permit =>
  if (checkConstraints){
history += event
event.getOwner ! Permit
  }
      case Deny => event.getOwner ! Deny
    }
case event : RA =>
    authorizer ! event
    receive{
case Permit =>
   if (!checkConstraints){
history += event
event.getOwner ! Permit
   }
case Deny => event.getOwner ! Deny
    }
    }
 }
}
```

```
Authorizer
def act(){
   initialize
   while(true){
      receive{
    case e: RA =>
     if (checkRA(e))  sender ! Permit
     else sender ! Deny
 case e: PA =>
     if (checkPA(e)) sender ! Permit
     else sender ! Deny
        case Stop =>
     exit()
      }
    }
}
```

```
User
def act(){
   var session : Session = createSession(generateRoleEntropy)
   while(true){
receive{
      case SessionPositive =>
         session.start
 sessions += session
 Thread.sleep(random.nextInt(500))
 session = createSession(generateRoleEntropy)
     case SessionNegative =>
 exit()
}
   }
}
```

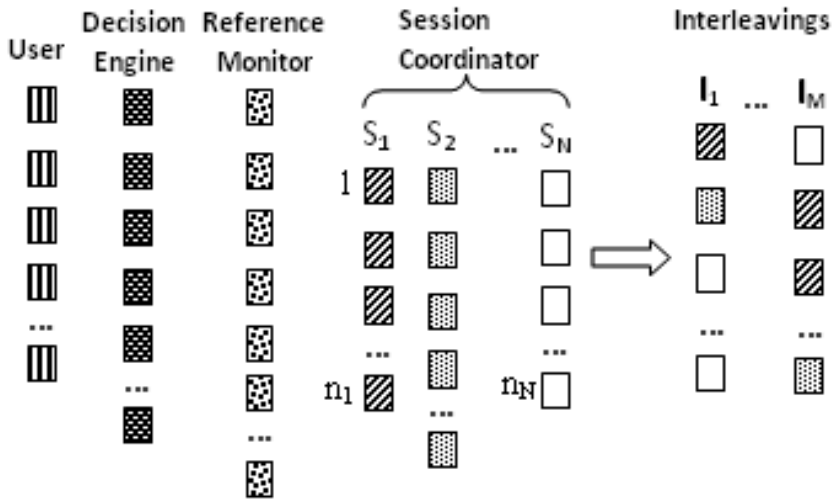
System Architecture



- Test cases (policies) initiate verification

1. User requests roles and permissions
2. Session information is given to coordinator
3. Coordinator asks Authorizer for decision

User behavior modeling



$$M = \frac{(\sum_{i=1}^{N} n_i)!}{\prod_{i=1}^{N} (n_i!)}$$

- Each session runs in its own thread
- Atomic operations are authorization events (A_R, D_R and A_P)

- Session creation
- A_R: Activating a Role
- D_R: Deactivating a Role
- A_P: Activation a Permission

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Three levels of verification

- Core simulation
  - partial simulation without run-time properties
  - e.g. race conditions, policy conflicts
- Symbolic evaluation
  - using some approximations of run-time properties
  - temporal and location parameters approximated
  - Monte Carlo simulation of parameters
- Monitor development
  - partial step-wise verification at run-time
  - just-in-time verification using Aspect Oriented Programming

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DMER support example

- Bob is in charge of Bravo account.
- Alice is out of office today.
- Bob covers of Alice today.
- Bob can audit accounts of Alice's junior accountants
- Bob can audit his own account?

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How DMER is supported

- Using Basset and Java Path Finder for verification
- Constraint: DMER
  - Given a new role activation request
  - Compute the intersection of all active roles and
  - the roles under DMER constraint
  - If the intersection of two sets is greater than a preset threshold
  - Deny the new role activation request

How DMER is supported (2)

- Encode RBAC, properties and the constraint checking function

```
def checkConstraints(ev:Event): Boolean{
 if (event.isInstanceOf[RA]){
    ract = ev.asInstanceOf[RA]
    if (ract != null) {
       //get the authorizer actor
   r = authorizer.getRoleFromID(ract.getRole)
   if subRoles is a subset of allActiveRoles &&
      subRoles is a subset of DMER1 &&
        subRoles.length == DMER1.getK()
          return false;
 ...
 }
}
```

- Execute JPF and Basset for state analysis.

```
..\jpf-core\bin\jpf +basset.language=scala
gov.nasa.jpf.actor.Basset Simulator
```

How DMER is supported (3)

- Bob is an Accountant of Bravo account
  - Bob cannot disable Accountant role on this object
- Bob requests to activate an Auditor role
- The activated roles = {Accountant}
- The roles under constraint = {Accountant, Auditor}
- The intersection = {Accountant}
- Threshold = 1
- Bob's request is denied

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Extra support

- Session concurrency
  - What if Bob logs in on two different computers?
  - Verification per session is not enough
  - Simultaneous sessions are evaluated together
    - if they touch the same object
- History support
  - support for Conflict of Interest, Chinese Wall policies
  - if Bob has been an accountant of this account in the past, then he is not eligible to audit this account

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Conclusion and Future work

- Conclusion
  - approximate run-time verification in static
  - can verify dynamic mutual exclusive roles

- Future work
  - support for more generic COI
  - large scale experiments for performance testing