ECS 289M Lecture 3

April 5, 2006

Overview

- Safety Question
- HRU Model
- Take-Grant Protection Model

What Is "Secure"?

- Adding a generic right *r* where there was not one is "leaking"
- If a system *S*, beginning in initial state s_0, cannot leak right *r*, it is *safe with respect to the right r*.

Safety Question

- Does there exist an algorithm for determining whether a protection system *S* with initial state s_0 is safe with respect to a generic right *r*?
  - Here, "safe" = "secure" for an abstract model

Mono-Operational Commands

- Answer: *yes*
- Sketch of proof:

  Consider minimal sequence of commands c_1, …, c_k to leak the right.

  – Can omit **delete**, **destroy**

  – Can merge all **create**s into one

  Worst case: insert every right into every entry; with *s* subjects and *o* objects initially, and *n* rights, upper bound is $k \leq n(s+1)(o+1)$

General Case

- Answer: *no*
- Sketch of proof:

  Reduce halting problem to safety problem

  Turing Machine review:

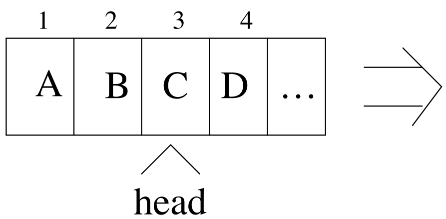
  – Infinite tape in one direction

  – States *K*, symbols *M*; distinguished blank *b*

  – Transition function $\delta(k, m) = (k', m', L)$ means in state *k*, symbol *m* on tape location replaced by symbol m', head moves to left one square, and enters state k'

  – Halting state is q_f; TM halts when it enters this state

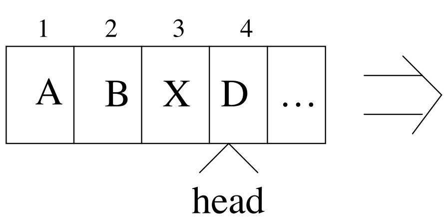
Mapping



Current state is k

	s_1	s_2	s_3	s_4	
s_1	A	*own*			
s_2		B	*own*		
s_3			C k	*own*	
s_4				D end	

Mapping



After $\delta(k, \mathrm{C}) = (k_1, \mathrm{X}, \mathrm{R})$ where k is the current state and k_1 the next state

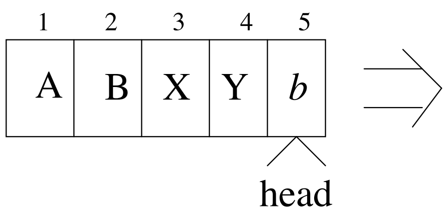
	s_1	s_2	s_3	s_4	
s_1	A	*own*			
s_2		B	*own*		
s_3			X	*own*	
s_4				D k_1 end	

Command Mapping

$\delta(k, C) = (k_1, X, R)$ at intermediate becomes

```
command c_{k,C}(s3,s4)
if own in A[s3,s4] and k in A[s3,s3]
     and C in A[s3,s3]
then
  delete k from A[s3,s3];
  delete C from A[s3,s3];
  enter X into A[s3,s3];
  enter k1 into A[s4,s4];
end
```


Mapping



	s_1	s_2	s_3	s_4	s_5
s_1	A	*own*			
s_2		B	*own*		
s_3			X	*own*	
s_4				Y	*own*
s_5					b k_2 end

After $\delta(k_1, D) = (k_2, Y, R)$ where k_1 is the current state and k_2 the next state

Command Mapping

$\delta(k_1, D) = (k_2, Y, R)$ at end becomes

```
command crightmost_{k,C}(s4,s5)
if end in A[s4,s4] and k1 in A[s4,s4]
      and D in A[s4,s4]
then
  delete end from A[s4,s4];
  create subject s5;
  enter own into A[s4,s5];
  enter end into A[s5,s5];
  delete k1 from A[s4,s4];
  delete D from A[s4,s4];
  enter Y into A[s4,s4];
  enter k2 into A[s5,s5];
end
```


Rest of Proof

- Protection system exactly simulates a TM
  - Exactly 1 *end* right in ACM
  - 1 right in entries corresponds to state
  - Thus, at most 1 applicable command
- If TM enters state q_f, then right has leaked
- If safety question decidable, then represent TM as above and determine if q_f leaks
  - Implies halting problem decidable
- Conclusion: safety question undecidable

Other Results

- Set of unsafe systems is recursively enumerable
- Delete **create** primitive; then safety question is complete in **P-SPACE**
- Delete **destroy**, **delete** primitives; then safety question is undecidable
  - Systems are monotonic
- Safety question for monoconditional, monotonic protection systems is decidable
- Safety question for monoconditional protection systems with **create**, **enter**, **delete** (and no **destroy**) is decidable.

Take-Grant Protection Model

- A specific (not generic) system
  - Set of rules for state transitions
- Safety decidable, and in time linear with the size of the system
- Goal: find conditions under which rights can be transferred from one entity to another in the system

System

- ○ objects (files, …)
- ● subjects (users, processes, …)
- ⊗ don't care (either a subject or an object)

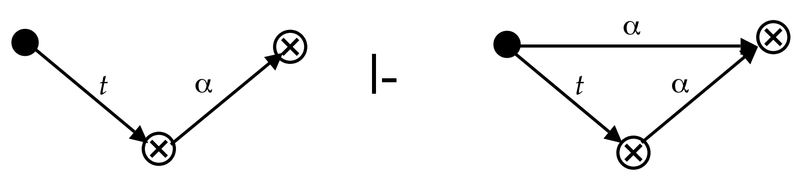
$G \vdash_x G'$ apply a rewriting rule *x* (witness) to G to get G'

$G \vdash^* G'$ apply a sequence of rewriting rules (witness) to G to get G'

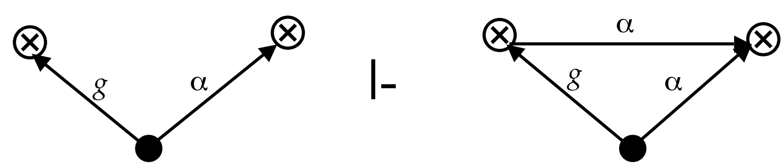
R = { *t*, *g*, *r*, *w*, … } set of rights

Rules

take



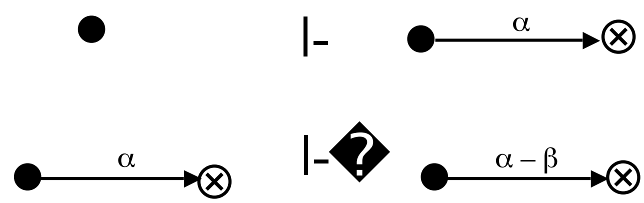
grant



More Rules

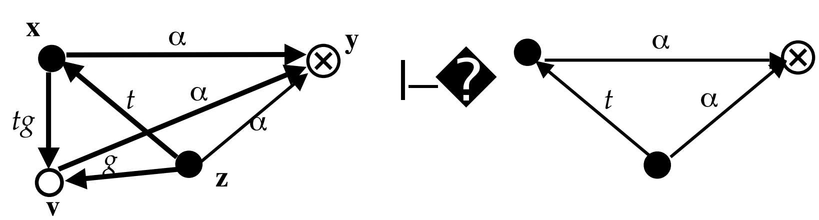
create

remove



These four rules are called the *de jure* rules

Symmetry



1. **x** creates (*tg* to new) **v**
2. **z** takes (*g* to **v**) from **x**
3. **z** grants (α to **y**) to **v**
4. **x** takes (α to **y**) from **v**

Similar result for grant

Islands

- *tg*-path: path of distinct vertices connected by edges labeled *t* or *g*
  – Call them "tg-connected"
- island: maximal *tg*-connected subject-only subgraph
  – Any right one vertex has can be shared with any other vertex

Initial, Terminal Spans

- *initial span* from **x** to **y**
  – **x** subject
  – *tg*-path between **x**, **y** with word in $\{ t^*g \} \cup \{ \nu \}$
  – Means **x** can give rights it has to **y**
- *terminal span* from **x** to **y**
  – **x** subject
  – *tg*-path between **x**, **y** with word in $\{ t^* \} \cup \{ \nu \}$
  – Means **x** can acquire any rights **y** has

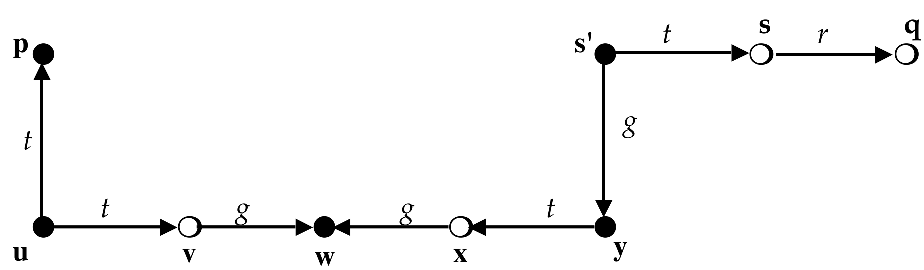
Bridges

- bridge: *tg*-path between subjects **x**, **y**, with associated word in

$$\{ \overrightarrow{t}^*, \overrightarrow{t}^*, \overrightarrow{t}^* \overleftarrow{g} \overleftarrow{t}^*, \overrightarrow{t}^* \overrightarrow{g} \overleftarrow{t}^* \}$$

  - rights can be transferred between the two endpoints
  - *not* an island as intermediate vertices are objects

Example



- islands { p, u } { w } { y, s' }
- bridges u, v, w; w, x, y
- initial span p (associated word ν)
- terminal span s's (associated word $\overrightarrow{t}$)

can•share Predicate

Definition:

- *can•share*(r, **x**, **y**, G_0) if, and only if, there is a sequence of protection graphs $G_0, \ldots, G_n$ such that $G_0 \vdash^* G_n$ using only *de jure* rules and in G_n there is an edge from **x** to **y** labeled r.

can•share Theorem

- *can•share*(r, **x**, **y**, G_0) if, and only if, there is an edge from **x** to **y** labeled r in G_0, or the following hold simultaneously:
  – There is an **s** in G_0 with an **s**-to-**y** edge labeled r
  – There is a subject **x′** = **x** or initially spans to **x**
  – There is a subject **s′** = **s** or terminally spans to **s**
  – There are islands $I_1, \ldots, I_k$ connected by bridges, and **x′** in I_1 and **s′** in I_k

Outline of Proof

- **s** has *r* rights over **y**
- **s**′ acquires *r* rights over **y** from **s**
  - Definition of terminal span
- **x**′ acquires *r* rights over **y** from **s**′
  - Repeated application of sharing among vertices in islands, passing rights along bridges
- **x**′ gives *r* rights over **y** to **x**
  - Definition of initial span

Example Interpretation

- ACM is generic
  - Can be applied in any situation
- Take-Grant has specific rules, rights
  - Can be applied in situations matching rules, rights
- Question: what states can evolve from a system that is modeled using the Take-Grant Model?

Take-Grant Generated Systems

- Theorem: G_0 protection graph with 1 vertex, no edges; R set of rights. Then G_0 |–* G iff:
  - G finite directed graph consisting of subjects, objects, edges
  - Edges labeled from nonempty subsets of R
  - At least one vertex in G has no incoming edges

Outline of Proof

⇒: By construction; G final graph in theorem

- Let $\mathbf{x}_1, \ldots, \mathbf{x}_n$ be subjects in G
- Let $\mathbf{x}_1$ have no incoming edges

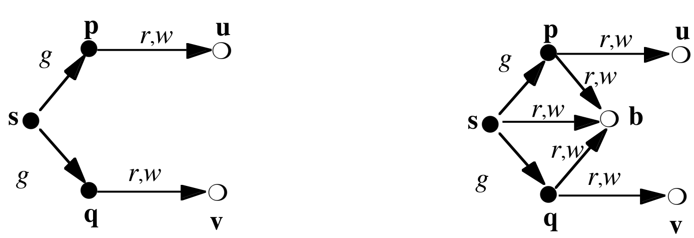
- Now construct G' as follows:
  1. Do "$\mathbf{x}_1$ creates ($\alpha \cup \{ g \}$ to) new subject $\mathbf{x}_i$"
  2. For all ($\mathbf{x}_i$, $\mathbf{x}_j$) where $\mathbf{x}_i$ has a rights over $\mathbf{x}_j$, do "$\mathbf{x}_1$ grants (α to $\mathbf{x}_j$) to $\mathbf{x}_i$"
  3. Let β be rights $\mathbf{x}_i$ has over $\mathbf{x}_j$ in G. Do "$\mathbf{x}_i$ removes (($\alpha \cup \{ g \} - \beta$ to) $\mathbf{x}_j$"
- Now G' is desired G

Outline of Proof

⇐: Let **v** be initial subject, and G_0 |–* G

- Inspection of rules gives:
  - *G* is finite
  - *G* is a directed graph
  - Subjects and objects only
  - All edges labeled with nonempty subsets of *R*
- Limits of rules:
  - None allow vertices to be deleted so **v** in *G*
  - None add incoming edges to vertices without incoming edges, so **v** has no incoming edges

Example: Shared Buffer



- Goal: **p**, **q** to communicate through shared buffer **b** controlled by trusted entity **s**
  1. **s** creates ({*r*, *w*} to new object) **b**
  2. **s** grants ({*r*, *w*} to **b**) to **p**
  3. **s** grants ({*r*, *w*} to **b**) to **q**