Chapter 3: Foundational Results

- Overview
- Safety Questions
- Turing Machine Mapping

Overview

- Safety Questions
- HRU 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*.
- What is a generic right?

Generic rights correspond to a class of objects

Definitions

- **Definition 3-1.** When a generic right *r* is added to an element of the access control matrix not already containing *r*, that right is said to be leaked.
- **Definition 3-2.** If a system can never leak the right *r*, the system (including the initial state s_0) is called *safe with respect to the right r*. If the system can leak the right *r* (enter an unauthorized state), it is called *unsafe with respect to the right r*.

Example

- A computer system allows the network administrator to read all network traffic. It disallows all other users from reading this traffic. The system is designed in such a way that the network administrator cannot communicate with other users. Is this system safe?

Yes, there is no way for the right *r* of the network administrator over the network device to leak.

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 $c_1, \ldots, c_k$ to leak the right r.

  –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 $k \le n(s+1)(o+1)$

General Case

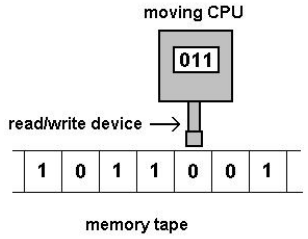
- Answer: *no*
- Sketch of proof:

  Reduce halting problem to safety problem

  Turing Machine review:

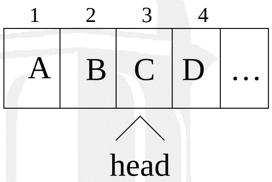
  – Infinite tape in one direction
  – States K, symbols M; distinguished blank b
  – Transition function $\delta(k, m) = (k', m', \mathrm{L})$ means in state k, symbol m on tape location replaced by symbol m', head moves to left one square, and enters state k'
  – Halting state is q_f; TM halts when it enters this state

Turing Machine



It is undecidable whether a given state of a given protection system is safe for a given generic right.

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

1	2	3	4	
A	B	X	D	…

head

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

$\delta(k, \mathrm{C}) = (k_1, \mathrm{X}, \mathrm{R})$ 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

1	2	3	4	5
A	B	X	Y	*b*

head

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

	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

Command Mapping

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

command crightmost$_{k,C}(s_4, s_5)$
if *end* **in** $A[s_4, s_4]$ **and** k_1 **in** $A[s_4, s_4]$
  and D **in** $A[s_4, s_4]$
then
  delete *end* **from** $A[s_4, s_4]$;
  create subject s_5;
  enter *own* **into** $A[s_4, s_5]$;
  enter *end* **into** $A[s_5, s_5]$;
  delete k_1 **from** $A[s_4, s_4]$;
  delete D **from** $A[s_4, s_4]$;
  enter Y **into** $A[s_4, s_4]$;
  enter k_2 **into** $A[s_5, s_5]$;
end

Rest of Proof

- Protection system exactly simulates a Turing Machine
  - 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**
- Safety question for mono-conditional, monotonic protection systems is decidable
- Safety question for mono-conditional protection systems with **create**, **enter**, **delete** (and no **destroy**) is decidable.

Key Points

- Safety problem undecidable
- Limiting scope of systems can make problem decidable