Security and Trust I: 2. Resource Security

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UHM ICS 355
Fall 2014

Outline

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Recall from Lecture 1

Resource security (access control)

- **authorization:** "bad *resource calls* don't happen"
- **availability:** "good *resource calls* do happen"

In an operating or a computer system

- all resource constraints are security properties

What is a resource?

A resource is whatever we (humans, animals, organisms) compete for.

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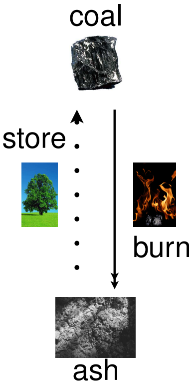
Examples

- territory, food, storage, energy. . .
- axe, printer, CPU, program. . .
- money, energy, reputation. . .

What is a resource?

But why do they compete for these things?

What is a resource?



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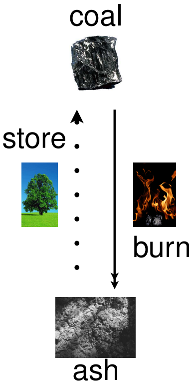

A resource is easy to use but hard to come by

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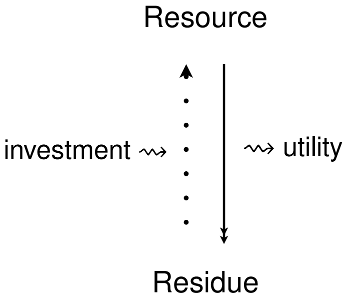

A resource is easy to use but hard to come by

What is a resource?

$$11,213 \times 756,839$$

attack $\rightsquigarrow$ $\uparrow$ $\downarrow$ $\rightsquigarrow$ system

$$8,486,435,707$$

A resource is a one-way function

What is a resource?

A resource is an **object** used in computation or in social interaction.

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A resource is an **object** used in computation or in social interaction.

A computer system or a social group

consists of

- subjects $\mathcal{S}$: people, users, agents, voters...
- objects $\mathcal{O}$: goods, devices, candidates...

Resources + security = assets

A resource that can be secured is an *asset*.

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Simplest resource security requirements

- privately **owned** assets: require authorization
  - den, shelter, home, account...
- publicly **shared** assets: require availability
  - well, path, printer, Internet...

Resources + security = assets

A resource that can be secured is an *asset*.

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Resource use in social and computational systems
is based on complex combinations of owning and sharing.

Security = Economy

Economy $\subseteq$ Security

- An asset is only an asset if it can be secured

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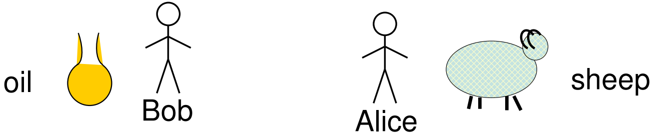
Security $\subseteq$ Economy

- A protection is only effective if it is cost effective

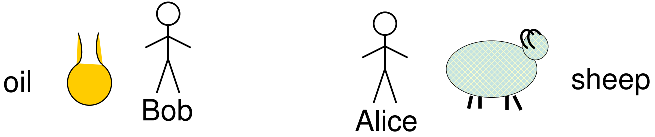
Access control

Privately owned resources



Access control

Privately owned resources

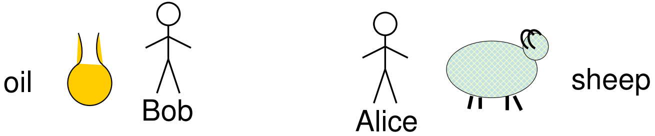


q_0		
	sheep	oil
Alice	use	$\emptyset$
Bob	$\emptyset$	use

Table : Permission matrix

Access control

...can be traded, jointly owned, partially shared etc.



$\mathbf{q}_1$		
	sheep	oil
Alice	{milk, wool}	cup oil
Bob	cup milk	use

Table : Permission matrix

Permission matrix

For the given sets

- $\mathcal{S}$ of subjects
- $\mathcal{O}$ of objects
- $\mathcal{A}$ of actions

a *permission matrix* at a state q is an assignment

$$\mathcal{S} \times \mathcal{O} \xrightarrow{M^q} \wp\mathcal{A}$$

- of the pairs $\langle u, i \rangle \in \mathcal{S} \times \mathcal{O}$ to
- to the sets (possibly empty) of actions $M^q_{ui} \subseteq \mathcal{A}$

which the subject u is permitted to execute on the object i.

Access matrix

For the given sets

- $\mathcal{S}$ of subjects
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an *access matrix* at a state q is an assignment

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Authorization

Access control is thus enforced by

- preventing the accesses in B_{ui}^{q}
- that are not permitted in M_{ui}^{q}.

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- preventing the accesses in B^q_{ui}
- that are not permitted in M^q_{ui}.

The operating system makes sure at every state q that

$$B^q_{ui} \subseteq M^q_{ui}$$

holds for every subject u and every object i.

Access control implementations

In UNIX-like operating systems,

- $\mathcal{S}$ = users
- $\mathcal{O}$ = files
- $\mathcal{A} = \{r, w, x\}$, i.e., read, write and execute

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Access Control Lists (ACL)

UNIX does not maintain large global matrices

$$\mathcal{S} \times \mathcal{O} \xrightarrow{M,B} \wp\mathcal{A}$$

but smaller object-based Access Control Lists

$$\mathcal{O} \rightarrow (\wp\mathcal{A})^U$$

where $U = \{u, g, o\}$, with $u \in \mathcal{S}$, $g \subseteq \mathcal{S}$ and $o = \mathcal{S}$.

Access control implementations

In UNIX-like operating systems,

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- $\mathcal{O}$ = files
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Capabilities

Symbian does not maintain large global matrices

$$\mathcal{S} \times \mathcal{O} \xrightarrow{M,B} \wp\mathcal{A}$$

but smaller *subject*-based *Capabilities*

$$\mathcal{S} \rightarrow \wp(\mathcal{O} \times \mathcal{A})$$

where each subject stores cryptographically protected capability tags $\langle i, a \rangle$.

Access control implementations

Homework

Read the about UNIX permission matrices (ACLs) in your favorite UNIX reference. What do the commands `chmod`, `setacl` and `getacl` do?

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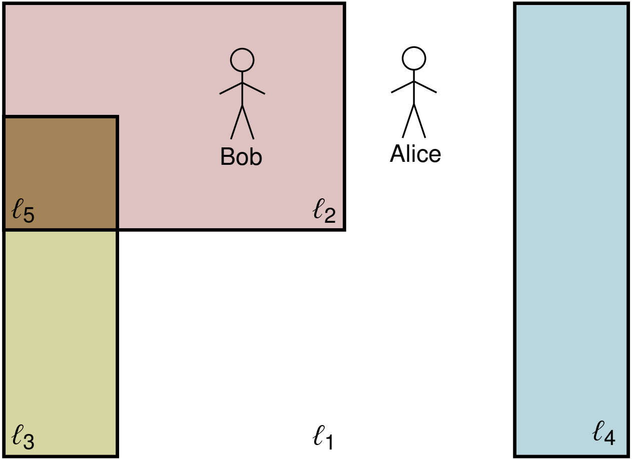
Compare the UNIX access control with the Windows access control. The paper *"Windows access control demystified"* by Govindavjahala and Appel may help.

Multi level security

In the meantime, at the dawn of Neolithic, Bob builds protected vaults ℓ_2 and ℓ_3, with a secure chamber ℓ_5.



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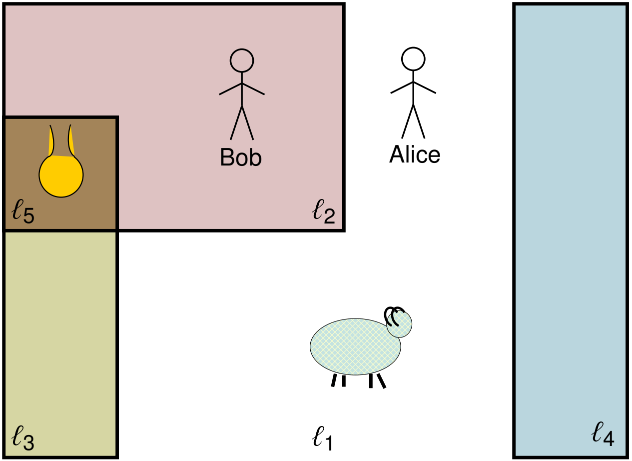
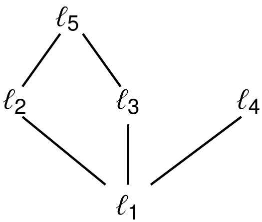


Security levels



$p\ell \leq c\ell$		
	location $p\ell$	clearance $c\ell$
Alice	ℓ_1	ℓ_1
Bob	ℓ_2	ℓ_5
sheep	ℓ_1	
oil	ℓ_5	

Clearance structure

For the given

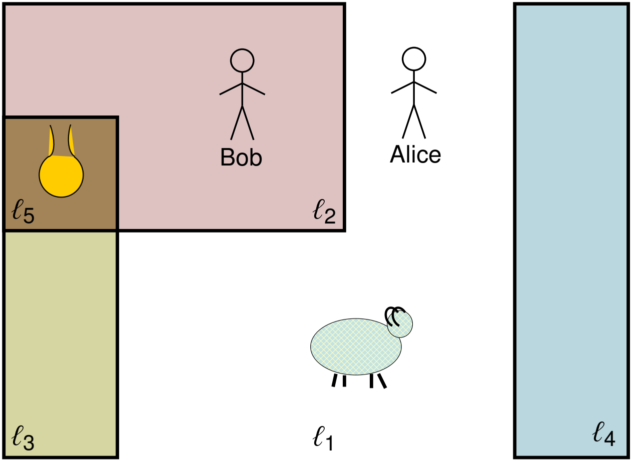
- set $\mathcal{S}$ of subjects
- set $\mathcal{O}$ of objects
- partially ordered set $\mathbb{L}$ of security levels

a *clearance structure* at a state q consists of the maps

- $c\ell^q : \mathcal{S} \to \mathbb{L}$ of *clearances*
- $p\ell^q_{\mathcal{S}} : \mathcal{S} \to \mathbb{L}$ of *subject locations* (or *places*)
- $p\ell^q_{\mathcal{O}} : \mathcal{O} \to \mathbb{L}$ of *object locations* (or *classifications*)

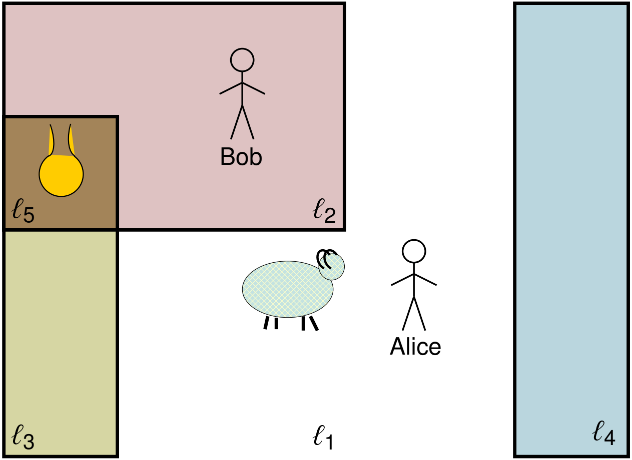
Maintaining multi level security

In the meantime, Alice and Bob agree



Maintaining multi level security: state q_0

In the meantime, Alice and Bob agree
to store Alice's sheep in Bob's protected vault ℓ_2.



Maintaining multi level security: state q_1

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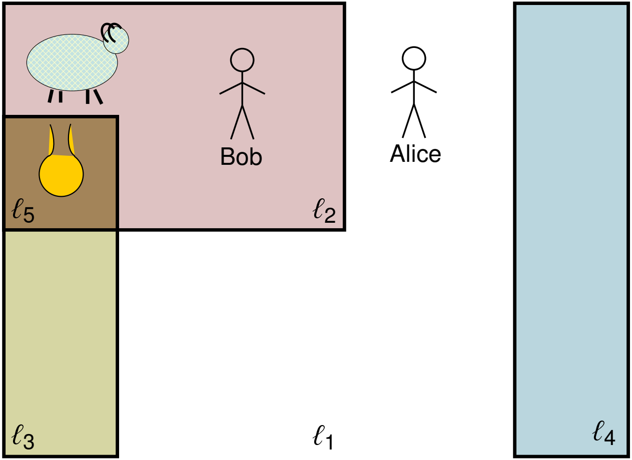

Maintaining multi level security: state q_1

As a receipt for the deposit of her sheep into Bob's vault, Alice gets a *secure token* in a clay envelope.

MS 4631
Bulla-envelope with 11 plain and complex tokens inside.
Near East, ca. 3700-3200 BC

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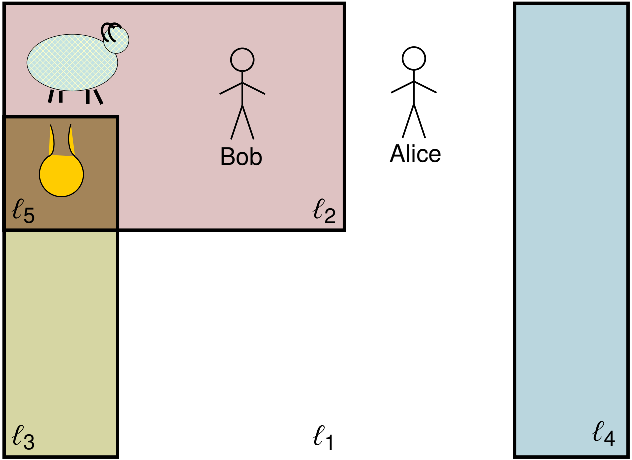
- To take the sheep, Alice must give the token.
- To give the sheep, Bob must take the token.
- Anyone who gives the token can take the sheep.

No-read-up: state q_1

Alice cannot take ("read") the sheep out of the vault, because she cannot enter there.



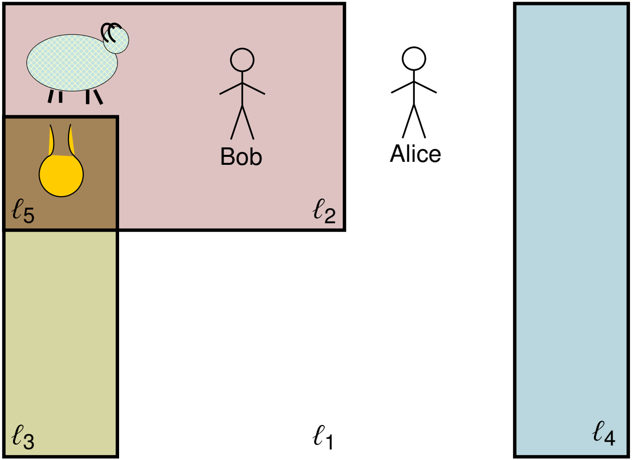
No-read-up: state q_1

Only a subject cleared to enter the vault can take ("read") an object from there

$$r \in B_{ui} \implies c\ell(u) \geq p\ell(i)$$

No-write-down: state q_1

Bob cannot give ("write") the sheep out of the vault while he is in there.



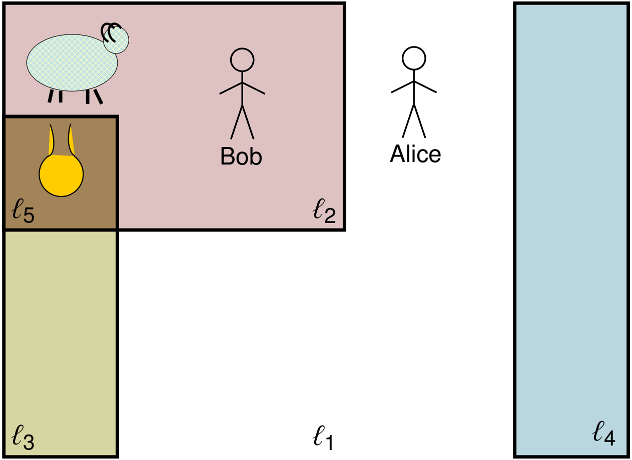
No-write-down: state q_1

Only a subject who is outside the vault can give ("write") an object there

$$w \in B_{ui} \implies p\ell(u) \leq p\ell(i)$$

Maintaining multi level security: state q_1

When Alice wants to take ("read") her sheep,



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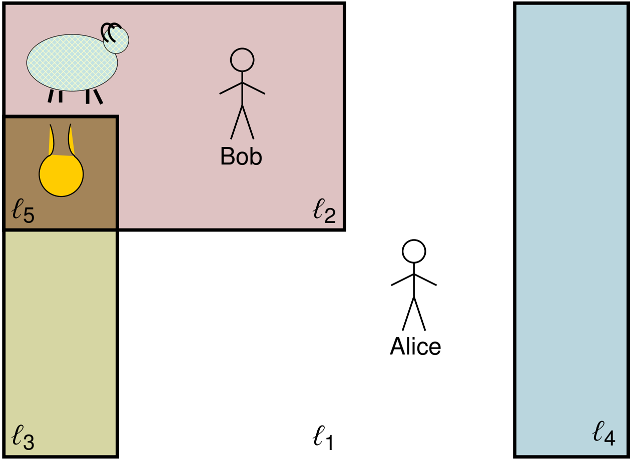
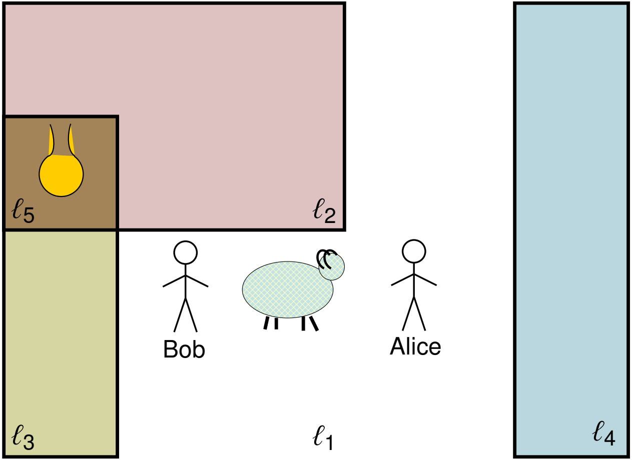


Maintaining multi level security: state q_2

When Alice wants to take ("read") her sheep, Bob comes out, breaks the token, and gives ("writes") the sheep.



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- The earliest **numeral systems** evolved from security annotations on the tokens.

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- **Money** evolved from resource security tokens.
- The earliest **numeral systems** evolved from security annotations on the tokens.
- The earliest **alphabets** evolved through book keeping of secure transactions.

History of Multi Level Security

- Access Controls and Multi Level Security are still organized around the same security models in all banks, companies, governments and computer systems.

Outline

Security model

Bell-LaPadula, Biba, Clark-Wilson

Given a state machine Q, describing the computation with

- a set $\mathcal{S}$ of subjects
- a set $\mathcal{O}$ of objects
- a set $\mathcal{A}$ of actions
- a poset $\mathbb{L}$ of security levels

a security model consists of the following data for each state $q \in Q$

- a permission matrix $M^q : \mathcal{S} \times \mathcal{O} \to \mathcal{A}$
- an access matrix $B^q : \mathcal{S} \times \mathcal{O} \to \mathcal{A}$
- a clearance map $c\ell^q : \mathcal{S} \to \mathbb{L}$
- a location map $p\ell^q : \mathcal{S} + \mathcal{O} \to \mathbb{L}$

Secure states

A state $q \in Q$ is said to be secure with respect to a model $\langle M, B, c\ell, p\ell \rangle$ if the following conditions are satisfied
for all subjects $u \in \mathcal{S}$ and objects $i \in \mathcal{O}$

- authorization: $B^q_{ui} \subseteq M^q_{ui}$,
- clearance: $p\ell^q(u) \leq c\ell^q(u)$
- no-read-up: $r \in B^q_{ui} \implies c\ell^q(u) \geq p\ell^q(i)$
- no-write-down: $w \in B^q_{ui} \implies p\ell^q(u) \leq p\ell^q(i)$

where $r, w \in \mathcal{A}$ are distinguished actions.

Secure states

Homework

Formalize the details of the described sheep bank protocol in terms of the multi level security model. Do not forget to include the clay token in the model, or else Bob may release the sheep to Eve.

Can Alice sell the sheep while in the vault?

Describe a similar protocol for digital content instead of the sheep.

Secure states

Warning

The terminology of "security models" and "secure states" can be misleading.

The modeling methodology itself does not guarantee security. There are models where the formally secure states are intuitively insecure.

Secure states

Example of the problem

Any security model can be extended by the transitions to a state z such that

$$\begin{aligned} c\ell^z(u) &= \top \\ p\ell^z(u) = p\ell^z(i) &= \bot \end{aligned}$$

where $\bot$ is the lowest and $\top$ the highest security level.

Secure states

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Comment

The state z corresponds to a situation where all security constraints are removed.

- This means that all resources are *declassified*.
- Declassification is a security operation.
- It should not be prevented, but controlled.

Secure states

Solution

In order to control

- *downgrading* of objects, and
- *authorization* of subjects

the state transitions must be constrained.

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This leads to the distinction of

- discretionary access control,
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- mandatory access control
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Secure states

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Many practical access control systems combine the two.

Outline

Denial of Service (DoS) attacks

Bob and Charlie go to Alice's restaurant. They did not book a table in advance. They don't get a table.

Annoyed, Bob and Charlie call next day, and book a lot of tables at Alice's. Through the evening, Alice turns back many guests. Bob and Charlie don't show up at all.

Distributed Denial of Service (DDoS) attacks

In the future, Alice attempts to prevent bogus bookings by authenticating the callers: she asks for a callback number. This makes booking a table more complicated.

If he is very motivated, Bob can still *distribute* the task of booking tables among his friends.

In response, Alice can attempt to *deter* bogus bookings by requiring a credit card number with each booking. To authenticate the cards, she has to authorize a small amount on each of them before the visit.

DoS attack on TCP: SYN flooding

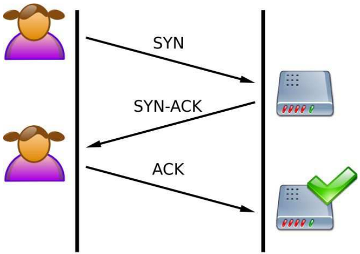

Figure : Normal 3-way handshake in TCP

DoS attack on TCP: SYN flooding

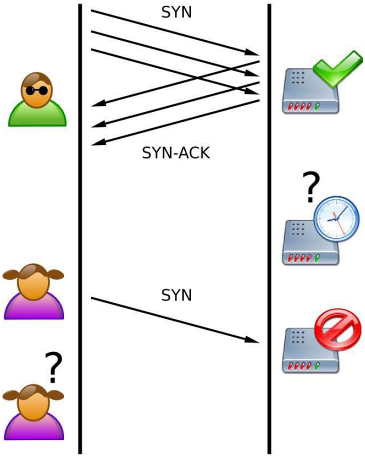

Figure : SYN flood: half open connections lock the server

DoS and DDoS as a sport

The network DDoS matches used to be a great passtime for unemployed botnets and for network engineers in search of adventure.

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The incentives seem to have weakened.

Commons: publicly shared resources

For centuries, Alice, Bob and Charlie have been sharing an **open field system**.

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Commons: publicly shared resources

In England, such open fields were called *Commons*.

Alice, Bob and Charlie alternated different crops with grazing, and maintained the land together.

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Two remarkable social processes ensued:

- Tragedy of the Commons, and
- Enclosure Movement

Tragedy of the Commons

Charlie realized that it was in his *rational* interest to invest

- all effort into exploiting the public resource, and
- no effort into maintaining it.

Charlie became a *free rider*.

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A *race to the bottom* ensued. The resource got depleted.

Tragedy of the Commons

Unrestricted access to a resource causes the race to the bottom.

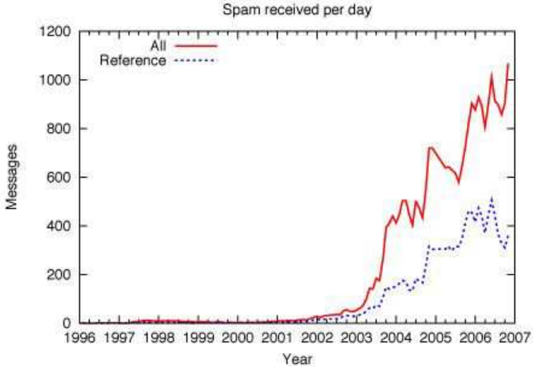
Tragedy of the Commons

Fair sharing of public resources is a security problem.

Tragedy of the Commons

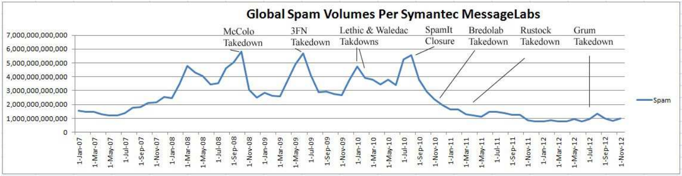
The Internet is a common resource.

Spam is a symptom of the Tragedy of the Commons.



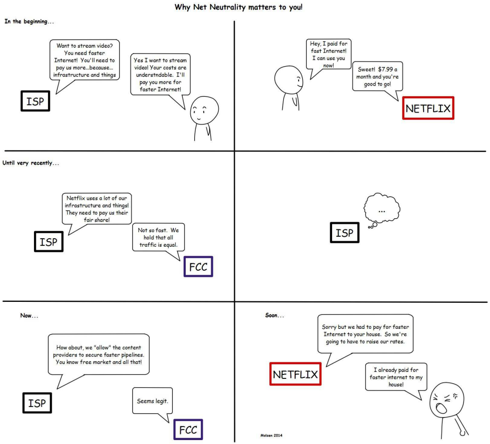
Tragedy of the Commons

But it turned out that fighting spam can be more profitable than distributing it.



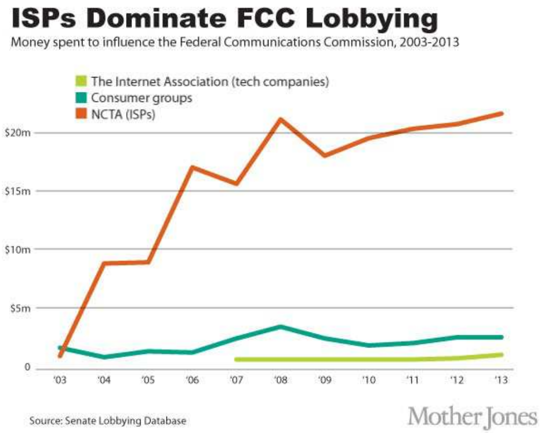
Enclosure

Enclosing the Internet as a private resource can be more profitable than **freeriding** on it as a public resource.



Enclosure Movement

The Second Enclosure Movement turned overtook the Tragedy of the Commons on the Internet.



Enclosure Movement

AT&T to FCC (Aug 2014)

AT&T appreciates this opportunity to comment on the petitions of the Electric Power Board of Chattanooga, Tennessee, and the City of Wilson, North Carolina, asking the Commission to act pursuant to section 706 of the Telecommunications Act of 19962 to preempt portions of Tennessee and North Carolina statutes that they claim restrict their ability to provide broadband services.

Enclosure Movement

AT&T to FCC (Aug 2014)

AT&T shares petitioners' desire to ensure that all Americans, including, but not limited to, those living in and around Chattanooga and Wilson, have access to world class broadband infrastructure. AT&T is skeptical, however, as to whether government owned networks (GONs) will help advance that goal.

Enclosure Movement

AT&T to FCC (Aug 2014)

Although AT&T does not necessarily oppose the use of GONs in areas where advanced infrastructure has not been, and is not likely to be, reasonably and timely deployed, we believe there are better and more effective ways of spurring broadband deployment in these areas. GONs should not receive any preferential tax treatment. Indeed, any tax incentives or exemptions should be provided, if at all, to private sector firms to induce them to expand broadband deployment to unserved areas.

Enclosure Movement

Download speeds (netindex.com)

1.	Hong Kong	78.89 Mbps	20.	Finland	31.11 Mbps
2.	Singapore	55.71 Mbps	21.	Estonia	30.62 Mbps
3.	Romania	55.64 Mbps	26.	USA	29.00 Mbps
4.	S. Korea	47.35 Mbps	27.	UK	27.40 Mbps
5.	Sweden	46.48 Mbps	31.	Israel	26.21 Mbps
6.	Lithuania	45.01 Mbps	33.	Japan	25.60 Mbps
10.	Latvia	37.83 Mbps	38.	Ukraine	23.27 Mbps
11.	Moldova	36.95 Mbps	41.	Canada	23.12 Mbps
12.	Iceland	34.82 Mbps		...	

Enclosure Movement

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Enclosure Movement

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In England, this happened in XV–XVII centuries.

Enclosure Movement

The law locks up the man or woman
Who steals the goose from off the common
But leaves the greater villain loose
Who steals the common from off the goose.

The law demands that we atone
When we take things we do not own
But leaves the lords and ladies fine
Who take things that are yours and mine.

The poor and wretched don't escape
If they conspire the law to break;
This must be so but they endure
Those who conspire to make the law.

The law locks up the man or woman
Who steals the goose from off the common
And geese will still a common lack
Till they go and steal it back.

Enclosure Movement

Homework

Read the article *"The Second Enclosure Movement and the Construction of the Public Domain"* by James Boyle.

Discuss and contrast the possible technical and political solutions of the security problems arising around modern Commons.

Can resources be beneficially secured?

Security policies

Security policies are both technical and political tools.

Can resources be beneficially secured?

Security policies

Security policies are both technical and political tools.

They regulate computation and social life,
as the processes of sharing and distributing resources.

Can resources be beneficially secured?

The question remains open from both sides.

Outline

Lesson

- Resource security is one of the oldest and the deepest social processes.
  - Already microorganisms compete to secure resources.
  - The first security protocols date back to 4000 B.C. They led to the invention of money and writing.
  - Our banks, our governments and our operating systems use similar security models.

Lesson

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  - public availability vs private ownership,
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  (For better or for worse.)
- Making math models is much easier ;)