Access Control

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Today

- Shellshock demo
- Access and information flow
- Access control mechanisms
- Multi-level security
- The BLP security model

Shellshock Demo

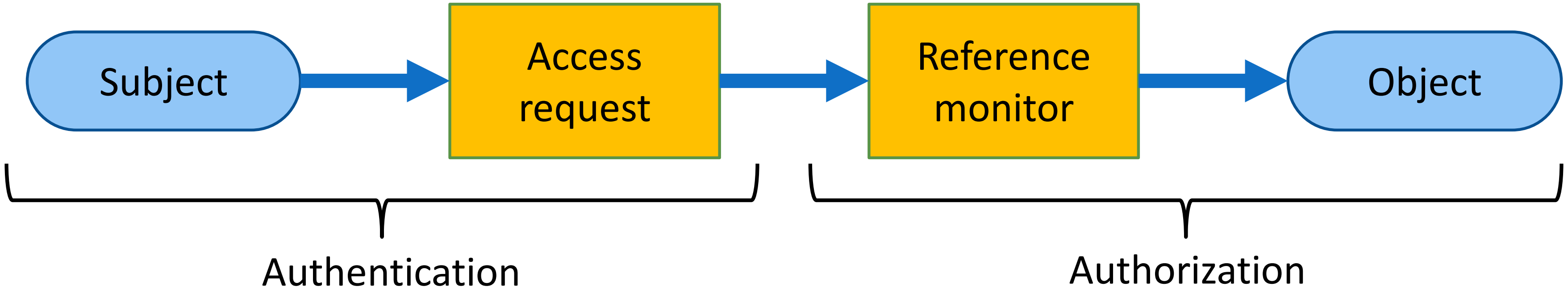
Access and information flow

System security policies and models

- A security policy describes requirements for a system.
- A security model is a framework with which a policy can be described.
- There are two basic paradigms:
  - Access control
  - Information flow control

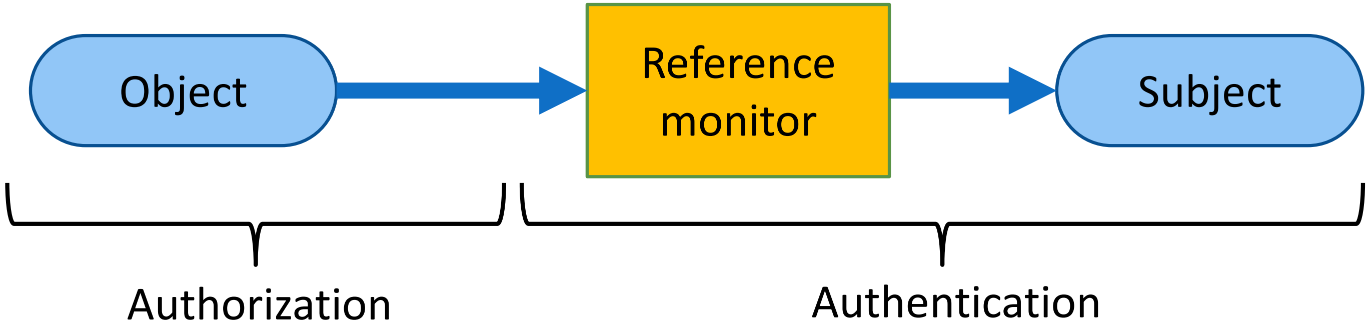
Access control

A guard controls whether a principal (the subject) is allowed access to a resource (the object).



Information flow control

A guard controls whether a principal (the subject) is allowed access to a resource (the object).



This is the dual notion, sometimes used when confidentiality is the primary concern.

The difference

- Access control
  - Starts with the subject (user) and asks if the user has access to the object.
- Information flow control
  - Starts with the object (information) and asks if that information can be known to the subject.

Access operations: modes and rights

- To define types of access, we define some fundamental **access modes** and **access rights**
- Modes are a way of accessing objects; rights are combinations of modes
- Access rights are the model's level of granularity for defining security policy. Each real operation requires particular access rights
- We will consider access modes and rights of the influential Bell-LaPadula (BLP) model
  - BLP enforces confidentiality
  - Other models enforce integrity, or a combination
  - Access management almost never considers avalibility

Access operations in BLP

- The access modes of BLP are:
  - **Observe**: examine contents of an object
  - **Alter**: change the contents of an object
- The access rights and their profiles are:

	Observe	Alter
Exec		
Read	X	
Append		X
Write	X	X

Profiles and names of rights differ between systems, or even for different subject kinds. E.g., sometimes have a delete. In Unix, exec for directories indicates ability to read the directory. The profile of rights used to define security properties in the model.

Who sets the policy?

- Discretionary Access Control (DAC)
  - The **owner** of a resource decides who may access that resource. Policy set on a case-by-case basis.
- Mandatory Access Control (MAC)
  - The decision of accessing resources is controlled **system-wide** by a uniform policy.

In practice a mixture of DAC and MAC may apply.

Ownership and identity

- Owners of resources may be principles in the system: subjects themselves under access control.
- BLP does not (directly) consider operations to modify access controls (e.g., chown in Linux), nor explain when such operations are safe.
- The identity of subjects is also flexible: e.g., identity changes during operations (SUID programs in Unix).
- Again, this doesn’t fit BLP.

Access control mechanisms

Access control matrix

How are access control rights defined? Many schemes but ultimately modelled by:

- A set *S* of subjects, a set *O* of objects
- A set *A* of operations (modeled by access rights), we consider *A={exec, read, append, write}*
- An **access control matrix**

$$M = (M_{so})_{s \epsilon S, o \epsilon O}$$

Where each entry $M_{so} \subseteq A$ defines rights for *s* to access *o*

- Example matrix for S={Alice,Bob} and three objects

	Bob.doc	Edit.exe	Fun.com
Alice	{}	{exec}	{exec, read}
Bob	{read, write}	{exec}	{exec, read, write}

Representing the access control matrix

- Implementing *M* directly is impractical, so different schemes are used. Complimentary possibilities: either use **capabilities** (store *M* by rows) or use **access control lists** (store *M* by columns)
- A **capability** is an unforgeable token that specifies a subject's access rights.
  - Pros: can pass around capabilities
  - Cons: difficult to revoke or find out who has access to a particular resources (you have to examine all capabilities)
- An **access control list** (ACL) stores the access rights to an object with the object itself.
  - Pros: good fit with object-biased OSes.
  - Cons: difficult to revoke, or find out, all permissions for a particular subject

alice VM from the exercise

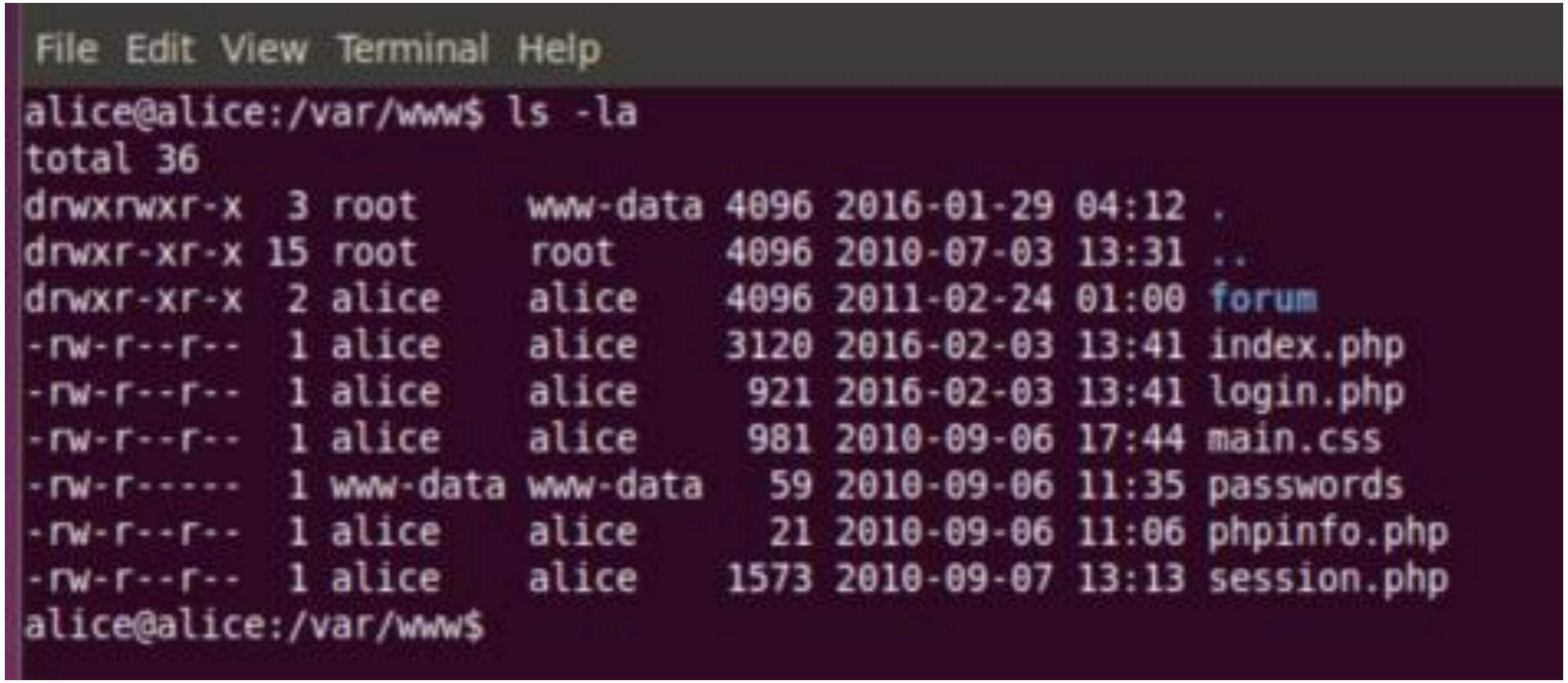
Three access rights

- r – read
- w – write
- x – exec

Three subjects:

- owner
- group
- world/other

- Access control list for each file and folder in the /var/www folder
- index.php can be read and written to by alice, anyone on the computer can read it



```
File  Edit  View  Terminal  Help
alice@alice:/var/www$ ls -la
total 36
drwxrwxr-x  3 root     www-data 4096 2016-01-29 04:12 .
drwxr-xr-x 15 root     root     4096 2010-07-03 13:31 ..
drwxr-xr-x  2 alice    alice    4096 2011-02-24 01:00 forum
-rw-r--r--  1 alice    alice    3120 2016-02-03 13:41 index.php
-rw-r--r--  1 alice    alice     921 2016-02-03 13:41 login.php
-rw-r--r--  1 alice    alice     981 2010-09-06 17:44 main.css
-rw-r-----  1 www-data www-data   59 2010-09-06 11:35 passwords
-rw-r--r--  1 alice    alice      21 2010-09-06 11:06 phpinfo.php
-rw-r--r--  1 alice    alice    1573 2010-09-07 13:13 session.php
alice@alice:/var/www$
```

Multi-level security

Multi-level security

- **Multi Level Security** (MLS) systems originated in the military. A **security level** is a label for subjects and objects, to describe a policy.
- Security levels are ordered:

$$\text{unclassified} \leq \text{confidential} \leq \text{secret} \leq \text{topsecret}.$$

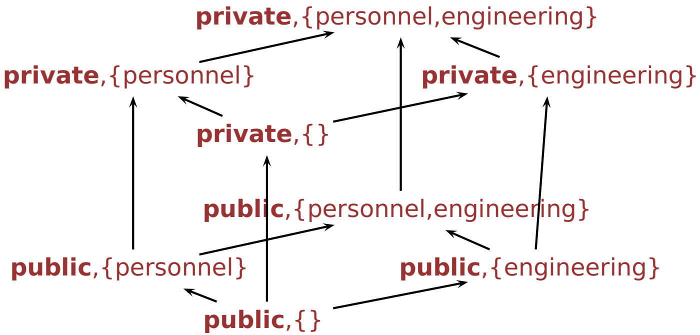
- Ordering can express policies like “no write-down” which means that a high-level subject cannot write down to a low-level object. (A user with confidential clearance cannot write an unclassified file: it might contain confidential information read earlier.)
- In practice, we need more flexibility. We may want *categorizations* as well, for example, describing departments or divisions in an organization. Then individual levels may not be comparable. . .

Security lattices

- A *lattice* is a set L equipped with a partial ordering $\leq$ such every two elements $a, b \in L$ has a *least upper bound* $a \vee b$ and a *greatest lower bound* $a \wedge b$. A finite lattice must have top and bottom elements.
- In security, if $a \leq b$, we say that b **dominates** a.
  - system low is the bottom, dominated by all others.
  - system high is the top, which dominates all others.
- Lattices are useful for MLS policies because:
  - for two *objects* at levels a and b, there is a minimal security level $a \vee b$ for a *subject* to access both;
  - for two *subjects* at levels a and b, there is a maximal security level $a \wedge b$ for an *object* which must be readable by both.

A Lattice Construction [Gollmann]

- take a set of *classifications* H and linear ordering $\leq_H$
- take a set C of categories; *compartments* are subsets of C
- *security levels* are pairs (h, c) with $h \in H$ and $c \subseteq C$
- ordering $(h_1, c_1) \leq (h_2, c_2) \iff h_1 \leq h_2, c_1 \subseteq c_2$ gives a lattice.



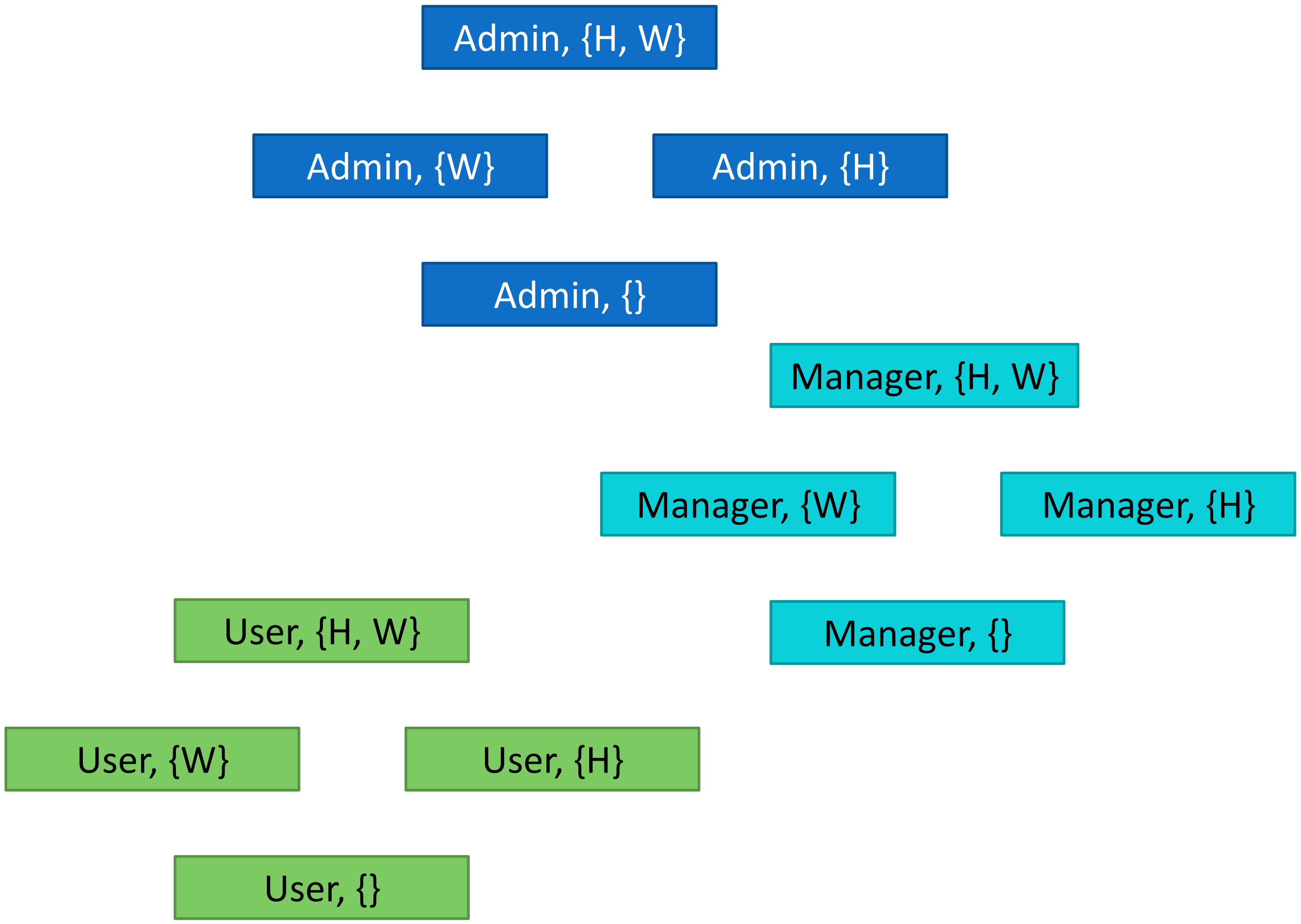
Running Example

Classifications (H)

- Admin
- Manager
- User

Categories (C)

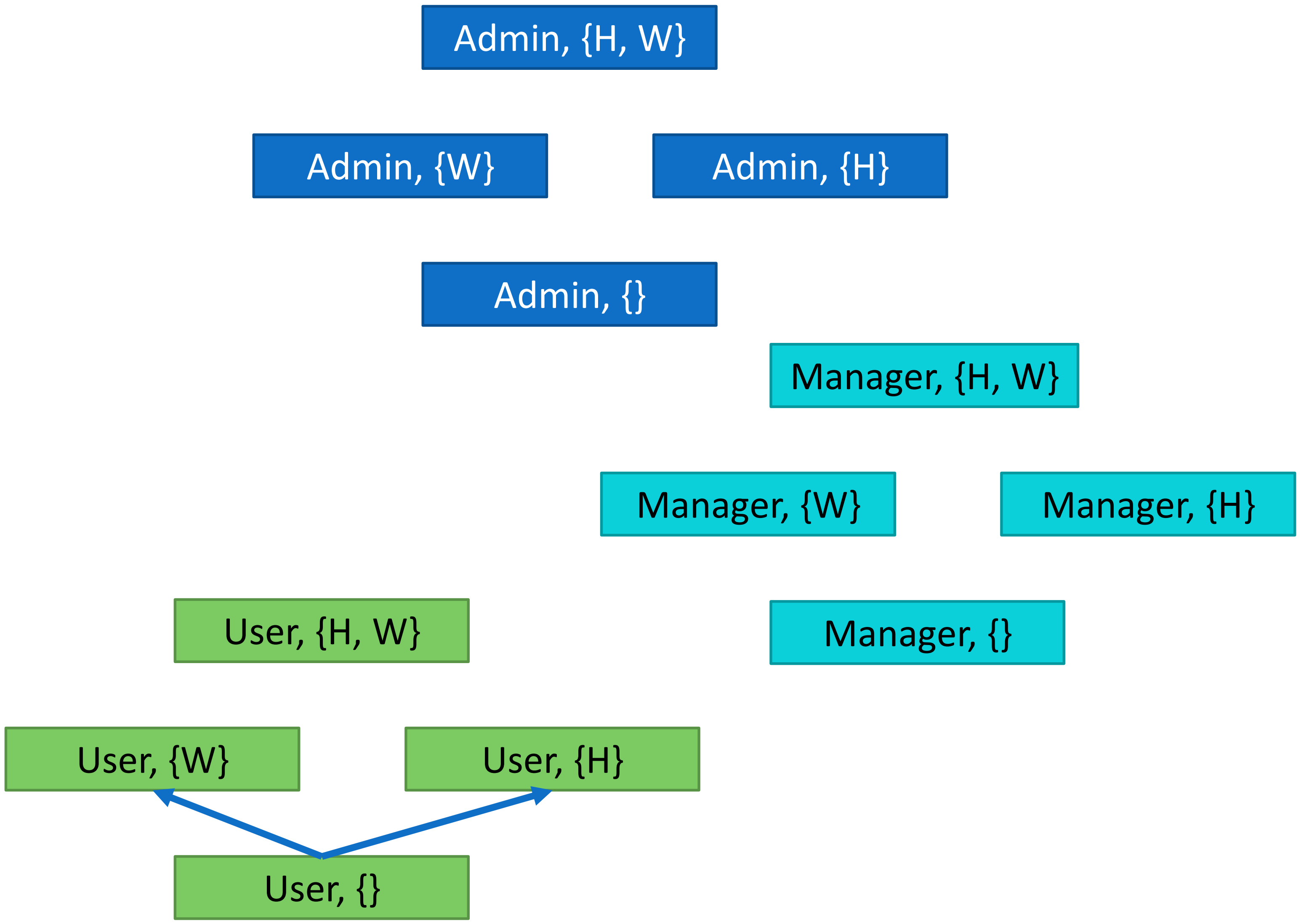
- H (Hippo project)
- W (Walrus project)



Orderings:

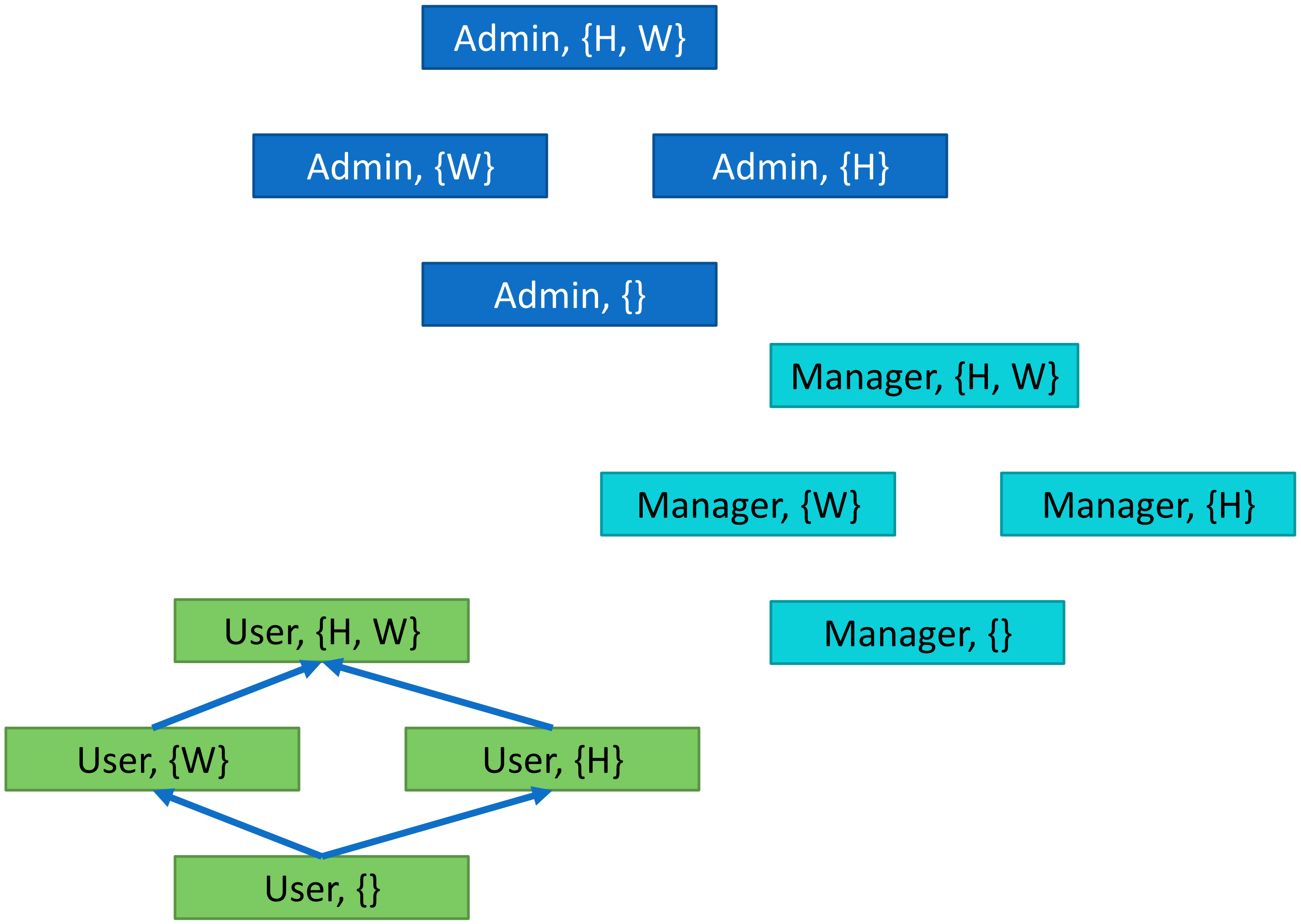
(User,{}) ≤ (User, {W})

(User,{}) ≤ (User, {H})



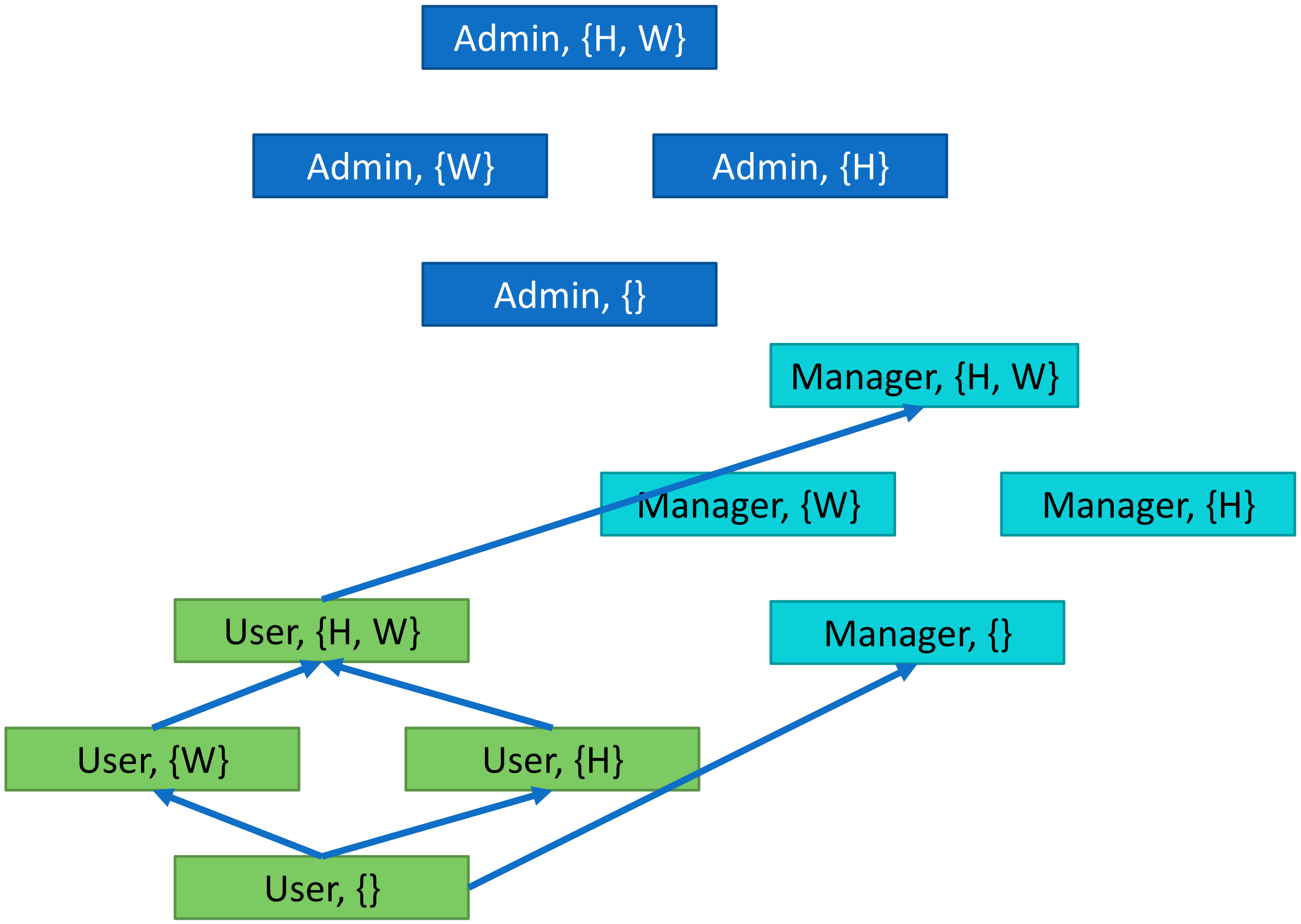
Orderings:

(User,{}) ≤ (User, {W})
(User,{}) ≤ (User, {H})
(User,{W}) ≤ (User, {H, W})
(User,{H}) ≤ (User, {H, W})



Orderings:

(User,{}) ≤ (User, {W})
(User,{}) ≤ (User, {H})
(User,{W}) ≤ (User, {H, W})
(User,{H}) ≤ (User, {H, W})
(User,{}) ≤ (Manager,{})
(User,{H,W})≤(Manager,{H,W})



Orderings:

(User,{}) ≤ (User, {W})
(User,{}) ≤ (User, {H})
(User,{W}) ≤ (User, {H, W})
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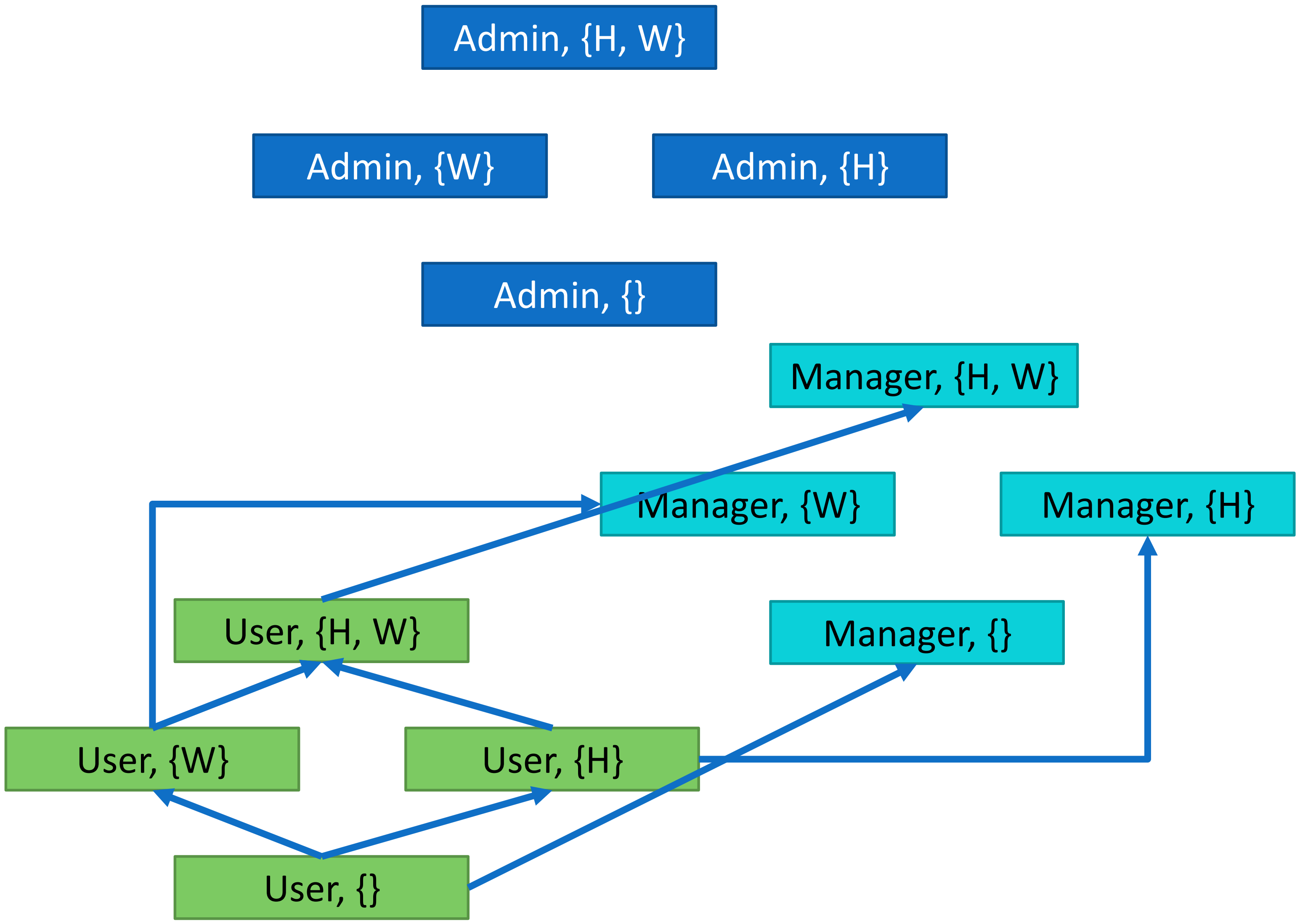
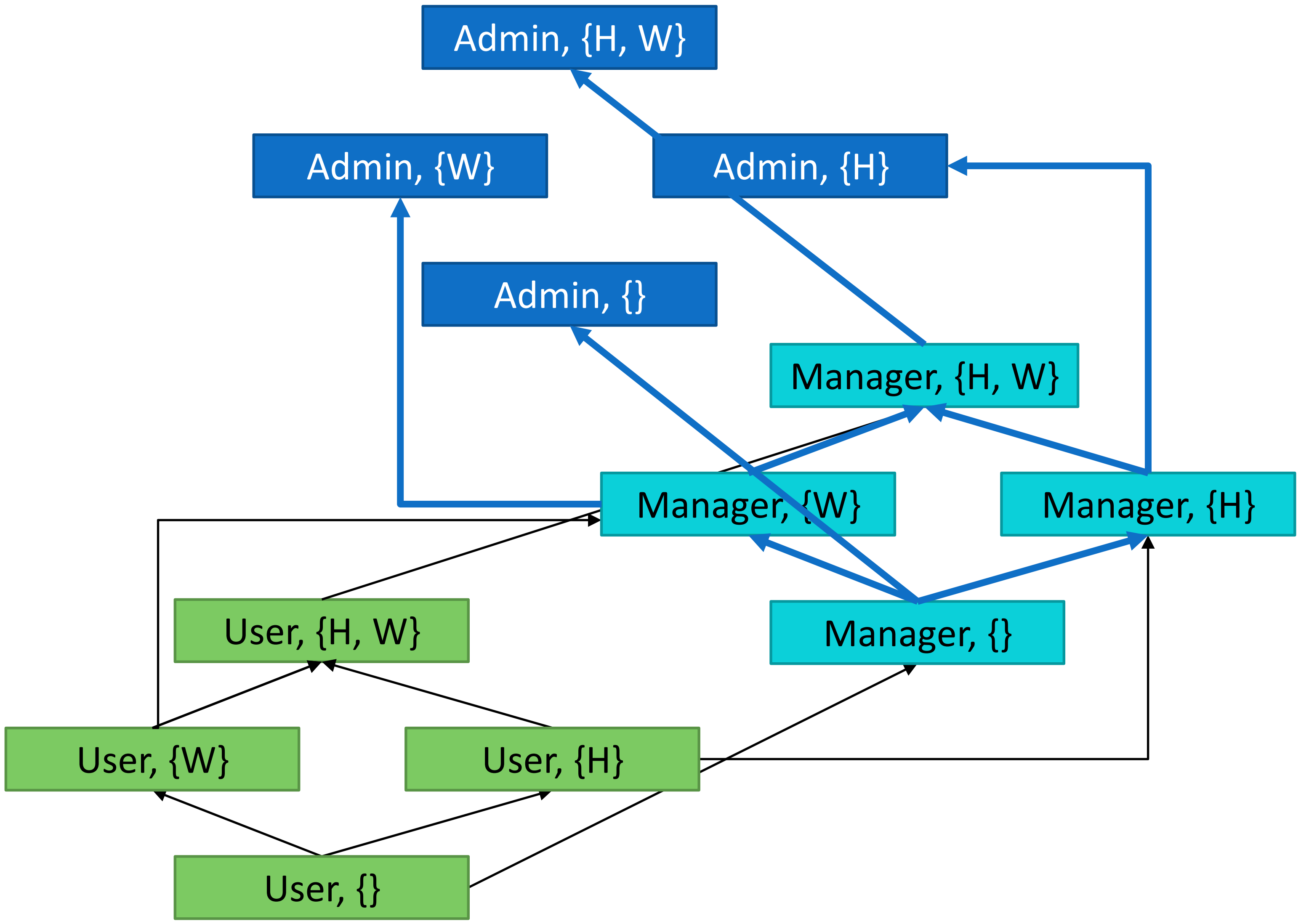


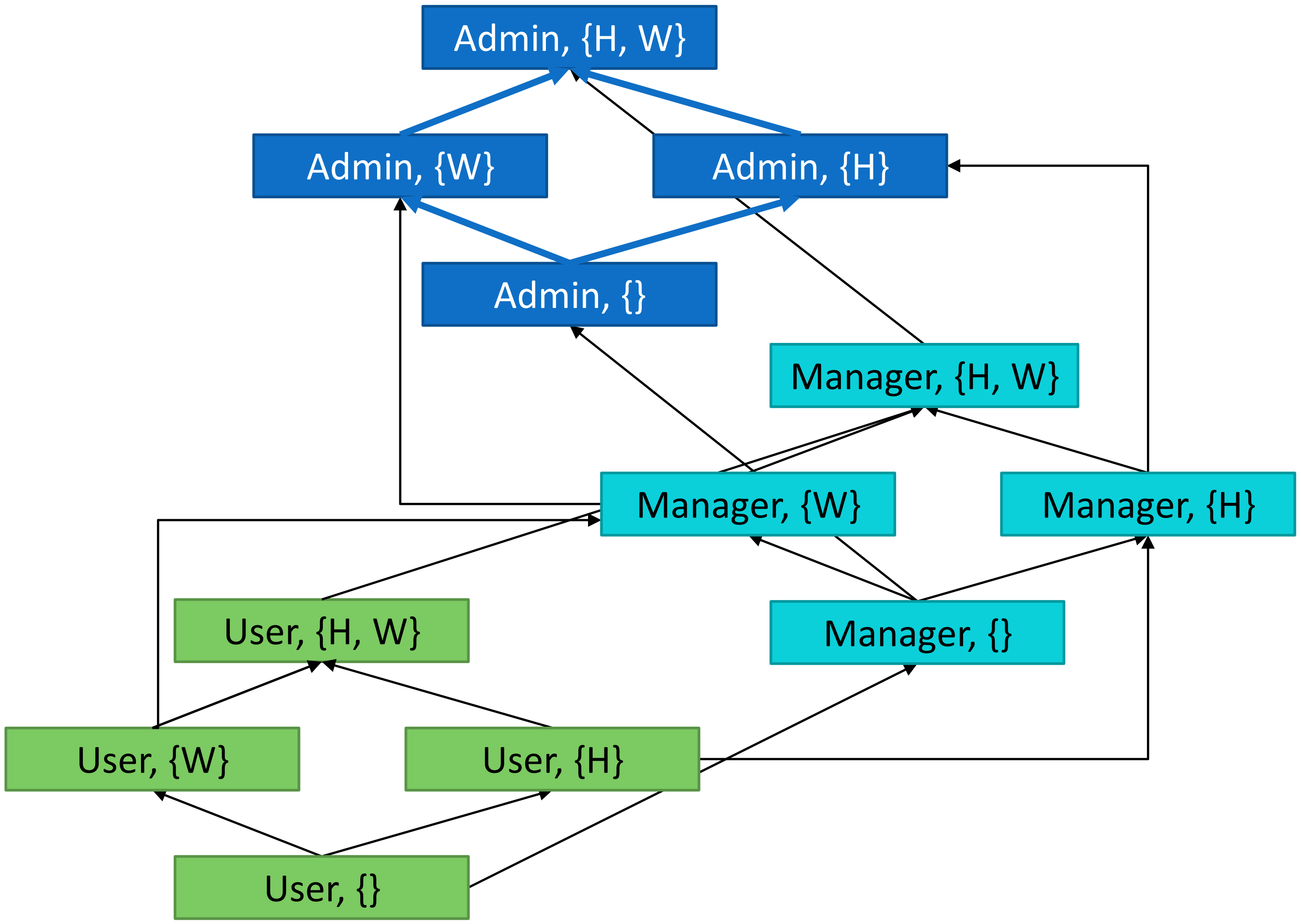
Orderings:

(Manager,{}) ≤ (Manager, {W})
(Manager,{}) ≤ (Manager, {H})
(Manager,{W}) ≤ (Manager, {H, W})
(Manager,{H}) ≤ (Manager, {H, W})
(Manager,{}) ≤ (Admin,{})
(Manager,{H,W})≤(Admin,{H,W})
(Manager,{W}) ≤ (Admin,{W})
(Manager,{H}) ≤ (Admin,{H})



Orderings:

(Admin,{}) ≤ (Admin, {W})
(Admin,{}) ≤ (Admin, {H})
(Admin,{W}) ≤ (Admin, {H, W})
(Admin,{H}) ≤ (Admin, {H, W})



Outline

- Access and information flow
- Access control mechanisms
- Multi-level security
- The BLP security model
- Summary

Bell-LaPadula Model (BLP)

- BLP (1973) is state machine model for confidentiality.
- Permissions use an AC matrix and **security levels**. The **security policy** prevents information flowing from a high level to a lower level.
- Assume subjects S, objects O, accesses A as before.
- A set L of security levels, with a partial ordering $\leq$.
- The state set $\mathcal{B} \times \mathcal{M} \times \mathcal{F}$ captures the current permissions and subjects accessing objects. It has three parts:
  - $\mathcal{B}$ possible current accesses
  - $\mathcal{M}$ permissions matrices
  - $\mathcal{F}$ security level assignments
- A BLP state is a triple (b, M, f).

BLP state set

- $\mathcal{B} = \mathcal{P}(S \times O \times A)$ is the set of all possible current accesses.
  An element $b \in B$ is a set of tuples (s, o, a) meaning s is performing operation a on an object o.
- $\mathcal{M}$ is the set of permission matrices $M = (M_{so})_{s \in S, o \in O}$.
- $\mathcal{F} \subset L^S \times L^S \times L^O$ is the set of security level assignments.
  An element $f \in \mathcal{F}$ is a triple (f_S, f_C, f_O) where
  - $f_S : S \to L$ gives the **maximal security level** each subject can have;
  - $f_C : S \to L$ gives the **current security level** of each subject (st $f_C \leq f_S$), and
  - $f_O : O \to L$ gives the **classification** of all objects.

BLP Model – B

- b is the set of all possible current accesses.
- An element of b is a set of tuples (subject, action, object)

b = [(Alice, FileA, write),
(Alice, FileA, read),
(Alice, FileA, exec),
(Bob, FileA, write),
(Bob, FileA, read),
(Charlie, FileA, read)]

BLP Model – M

- M is the set of permission matrices

	FileA	FileB	FileC
Alice	{read, write, exec}	{read, write}	{exec}
Bob	{read, write}	{read}	{}
Charlie	{read, write}	{}	{}

BLP Model – F

- F is the set security level assignments
- An element of F is a triple (f_S, f_C, f_O)
- f_S - Maximal security level
- f_C - Current security level
- f_O - Classification

$$
\begin{aligned}
L_S = [&Alice \longmapsto (Admin, \{W, H\}),\\
&Bob \longmapsto (Manager, \{H\}),\\
&Charlie \longmapsto (User, \{H\})]
\end{aligned}
$$

$$
\begin{aligned}
L_C = [&Alice \longmapsto (Manager, \{H\}),\\
&Bob \longmapsto (Manager, \{H\}),\\
&Charlie \longmapsto (User, \{H\})]
\end{aligned}
$$

$$
\begin{aligned}
L_O = [&FileA \longmapsto (User, \{H\}),\\
&FileB \longmapsto (Manager, \{H\}),\\
&\text{FileC} \longmapsto (Admin, \{H\})]
\end{aligned}
$$

BLP Mandatory Access Control Policy

Consider a state (b, M, f), where b is the set of current accesses.

Simple security property

The **ss-property** states for each access $(s, o, a) \in b$ where $a \in \{\text{read}, \text{write}\}$, then $f_O(o) \leq f_S(s)$ (*no read-up*).

Star property

The $*$**-property** states for each access $(s, o, a) \in b$ where $a \in \{\text{append}, \text{write}\}$, then $f_C(s) \leq f_O(o)$ (*no write-down*) and moreover, we must have $f_O(o') \leq f_O(o)$ for all o' with $(s, o', a') \in b$ and $a' \in \{\text{read}, \text{write}\}$ (*o must dominate any other object s can read*).

Together these form the *mandatory access control* policy for BLP.

BLP Discretionary Control and Security

The access control matrix M allows DAC as well.

Discretionary security property

The **ds-property**: for each access $(s, o, a) \in b$, we have that $a \in M_{so}$ (*discretionary access controls are obeyed*).

- **Definition of Security:** The state (b, M, f) is **secure** if the three properties above are satisfied.

Notice that BLP's notion of security is entirely captured in the current state.

Current clearance level

- Unfortunately, the $\ast$-property means a high-level subject cannot send messages to a low-level subject. This is unrealistic!
- There are two ways out:
  1. temporarily downgrade a high-level subject, which is why the model includes the current **clearance level** setting f_C, or
  2. identify a set of **trusted subjects** allowed to violate the $\ast$-property.
- Approach 1 works because the current state describes exactly what each subject knows. So if a subject (e.g. a process) is downgraded, it cannot access higher-level material, so may safely write at any lower level than its maximum.
- When subjects are people with high-level clearances, approach 2 works: we trust someone to violate the property in the model, e.g., by publishing part of a secret document.

Basic security theorem

- A transition from state v_1 to v_2 is **secure** simply if both states v_1 and v_2 are secure.
- This leads to a rather simple and general theorem:

Basic security theorem

If all state transitions in a system are secure and the initial state of the system is secure, then every subsequent state is also secure.

(NB: this follows immediately by induction, it has nothing to do with the properties of BLP!)

- The point: we can reduce checking the system for all possible inputs to checking that each kind of possible state transition preserves security. Of course, to do this we need a concrete instance of the model which describes possible transitions.

Questions

References

See Chapters 5, 11 (also 7 and 8) of Gollmann, and Parts 2–3 of Bishop.

- Ross Anderson. *Security Engineering: A Guide to Building Dependable Distributed Systems.*. Wiley & Sons, 2nd Edition, 2008.
- Matt Bishop. *Computer Security: Art and Science*. Addison-Wesley, 2003.
- Dieter Gollmann. *Computer Security*. John Wiley & Sons, 3rd Edition, 2011.

Recommended Reading

Chapters 5 and 11 of Gollmann.
Chapters 4 and 8 of Anderson.