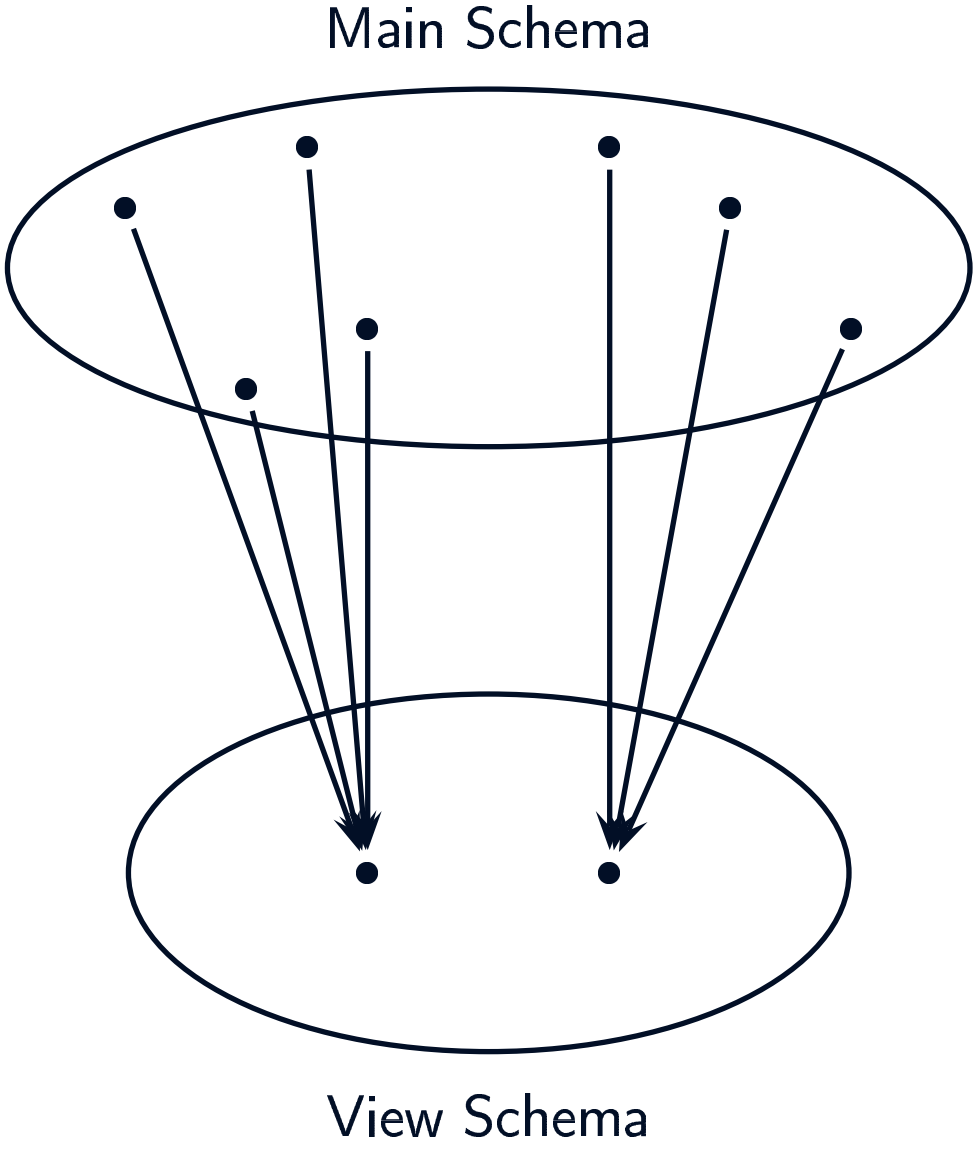
Update Support for Database Views via Cooperation

Stephen J. Hegner
Umeå University
Department of Computing Science
Sweden

Peggy Schmidt
Christian-Albrechts-University of Kiel
Department of Computer Science
Germany

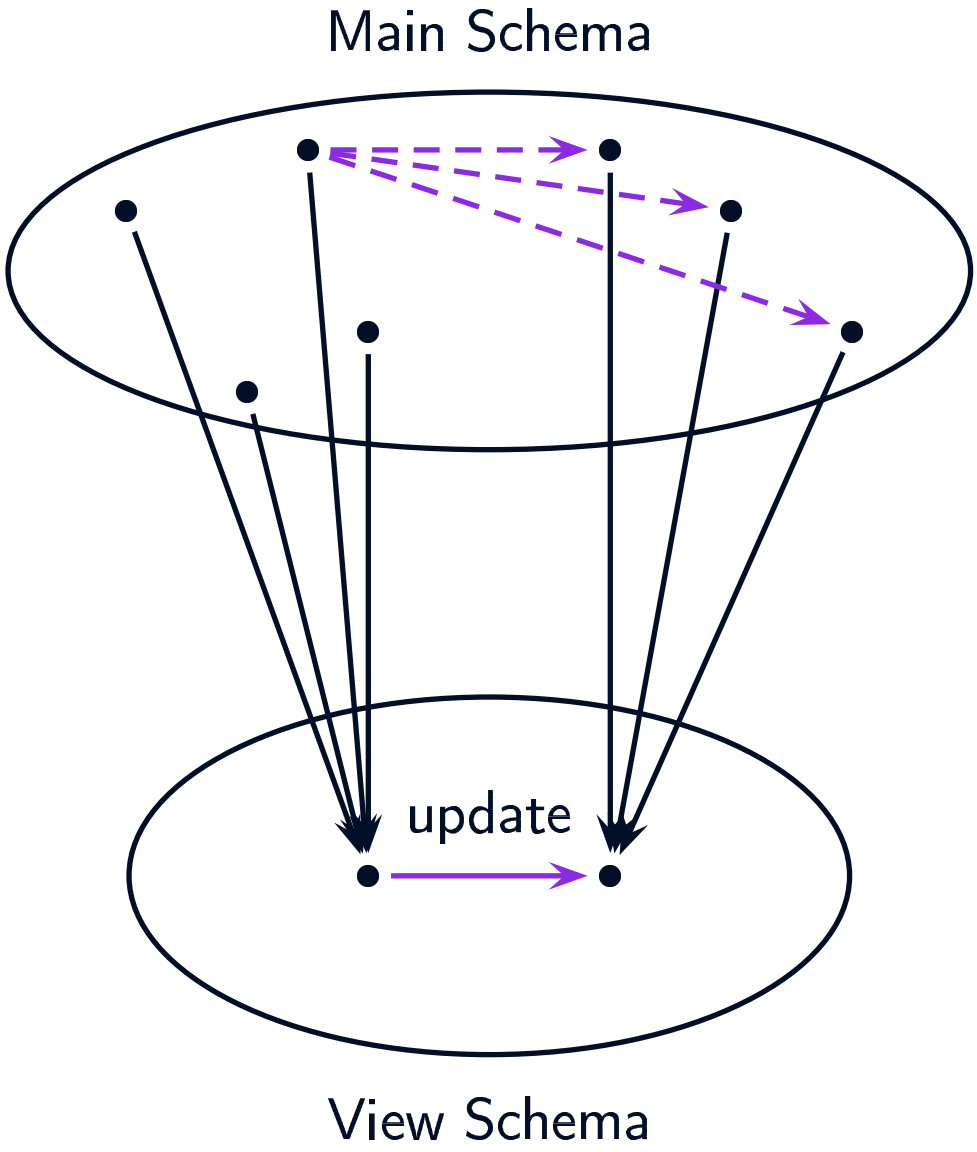
The Update Problem for Database Views

- On the underlying states, the view mapping is generally *surjective* (onto) but not *injective* (one-to-one).



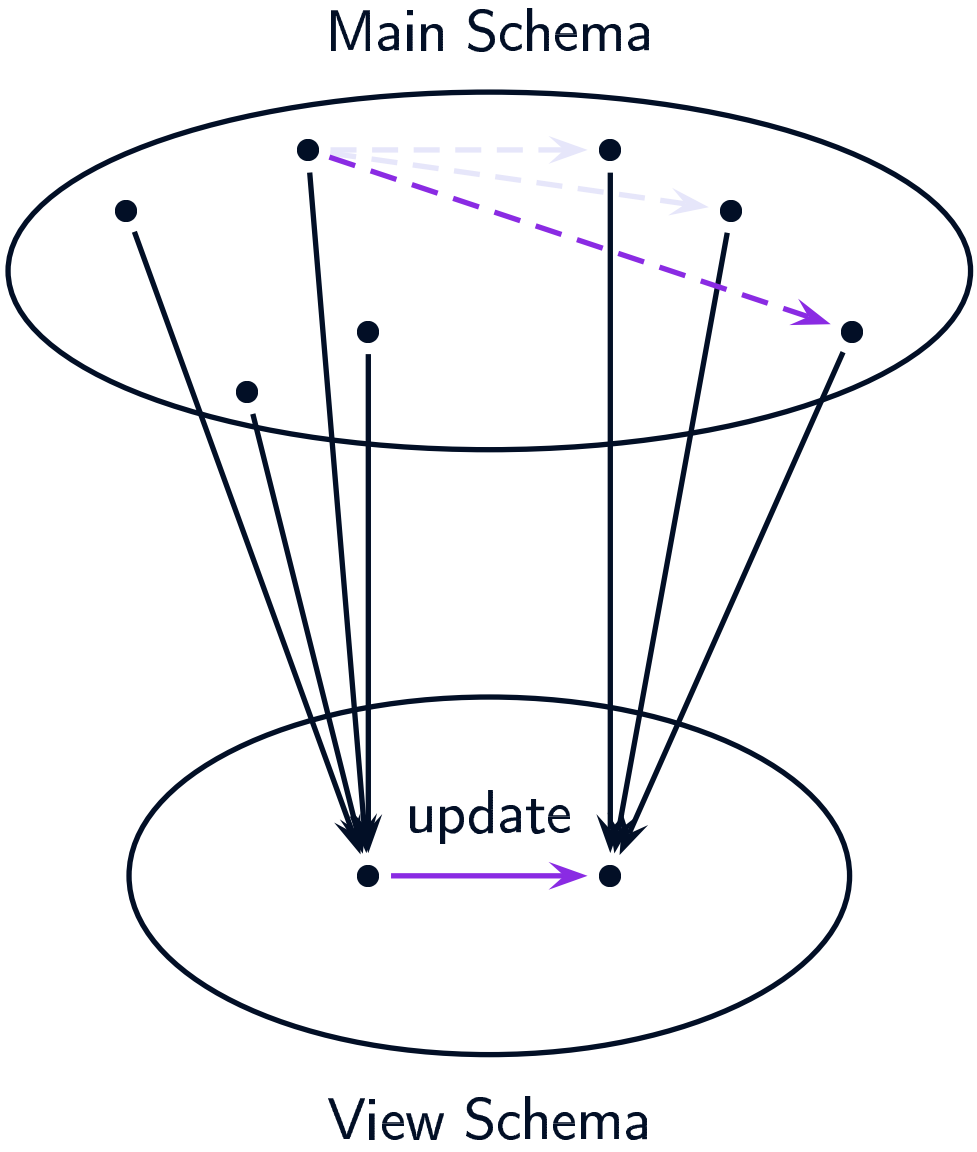
The Update Problem for Database Views

- On the underlying states, the view mapping is generally *surjective* (onto) but not *injective* (one-to-one).
- Thus, a view update has many possible *reflections* to the main schema.



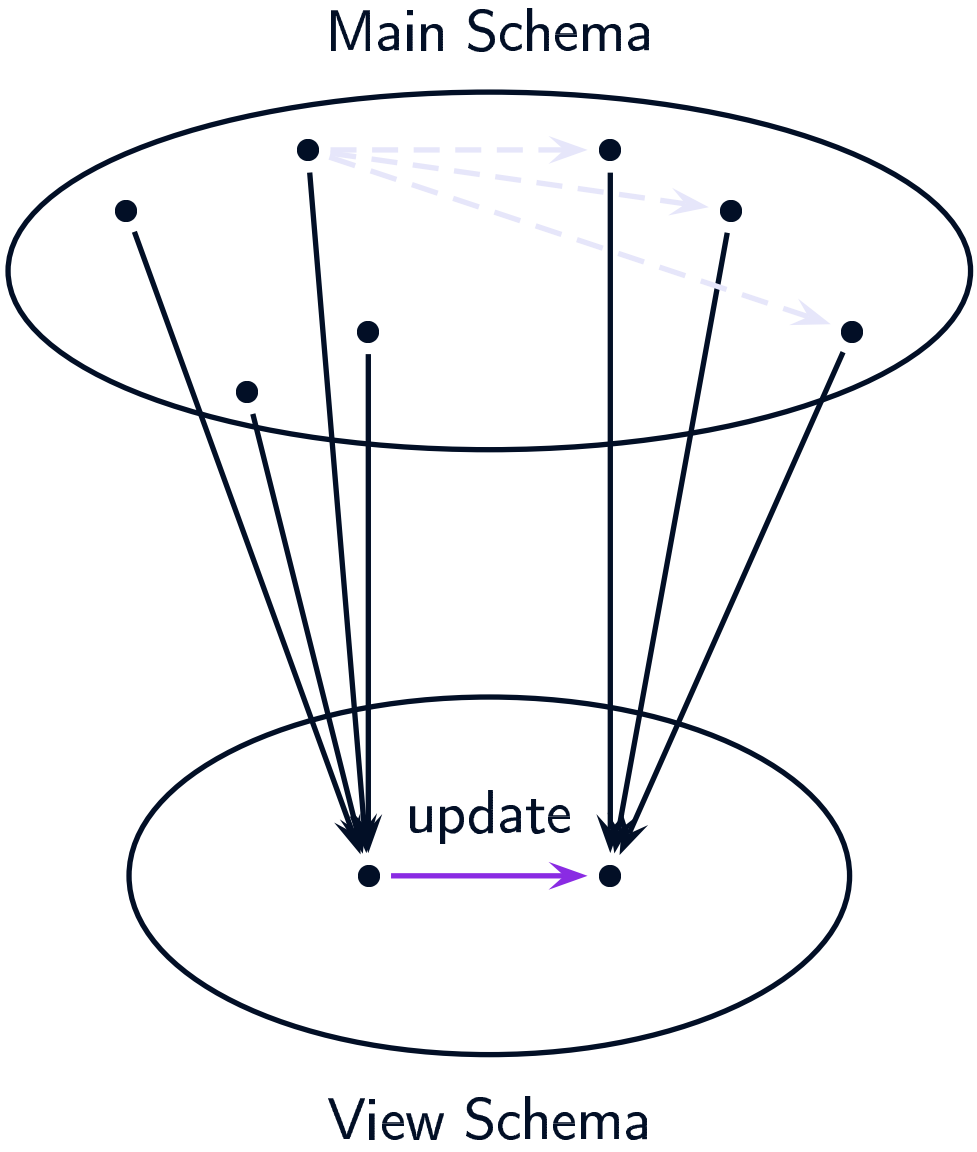
The Update Problem for Database Views

- On the underlying states, the view mapping is generally *surjective* (onto) but not *injective* (one-to-one).
- Thus, a view update has many possible *reflections* to the main schema.
- The problem of identifying a suitable reflection is known as the *update translation problem* or *update reflection problem*.

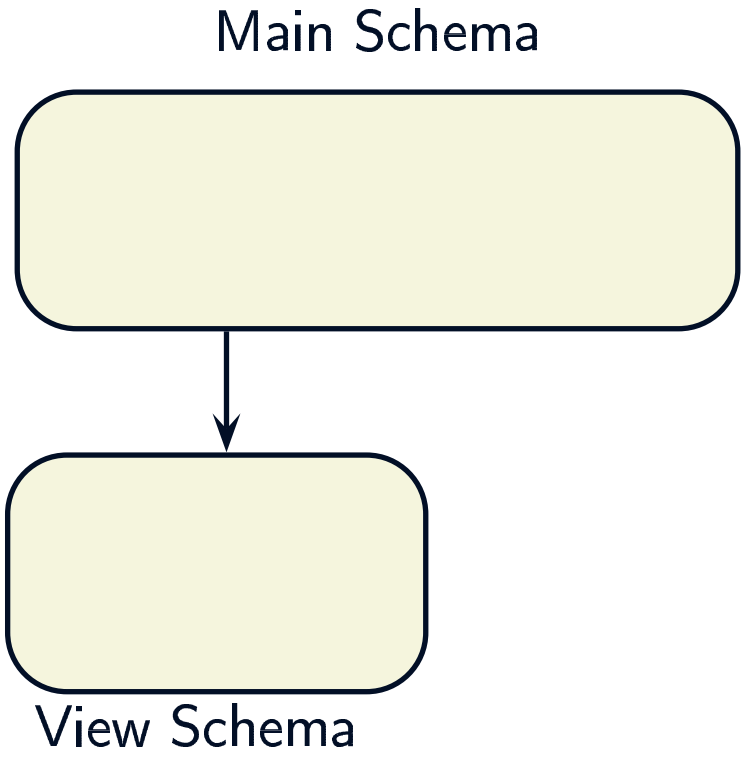


The Update Problem for Database Views

- On the underlying states, the view mapping is generally *surjective* (onto) but not *injective* (one-to-one).
- Thus, a view update has many possible *reflections* to the main schema.
- The problem of identifying a suitable reflection is known as the *update translation problem* or *update reflection problem*.
- With a reasonable definition of suitability, it may not be the case that every view update has a suitable translation.

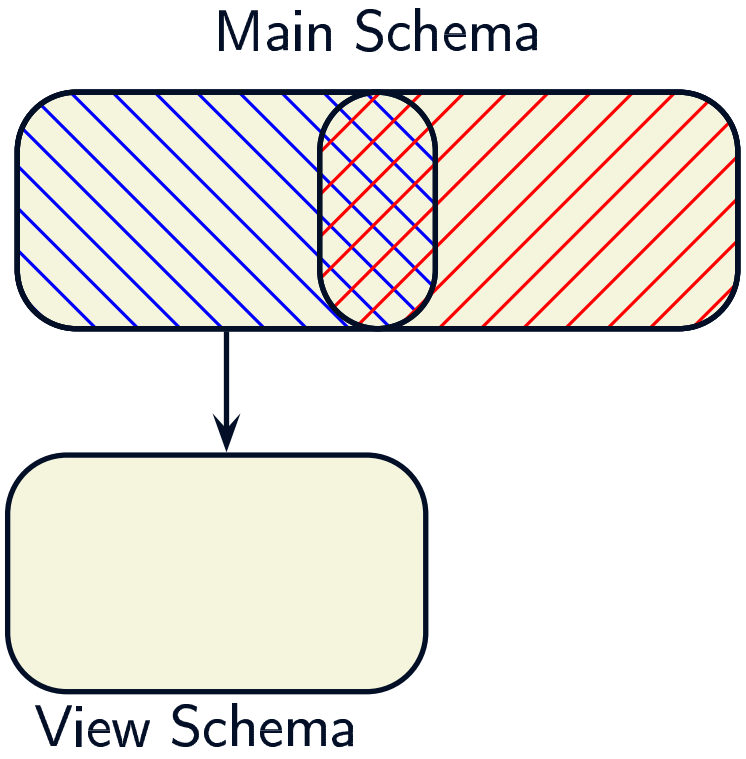


The Constant-Complement Strategy



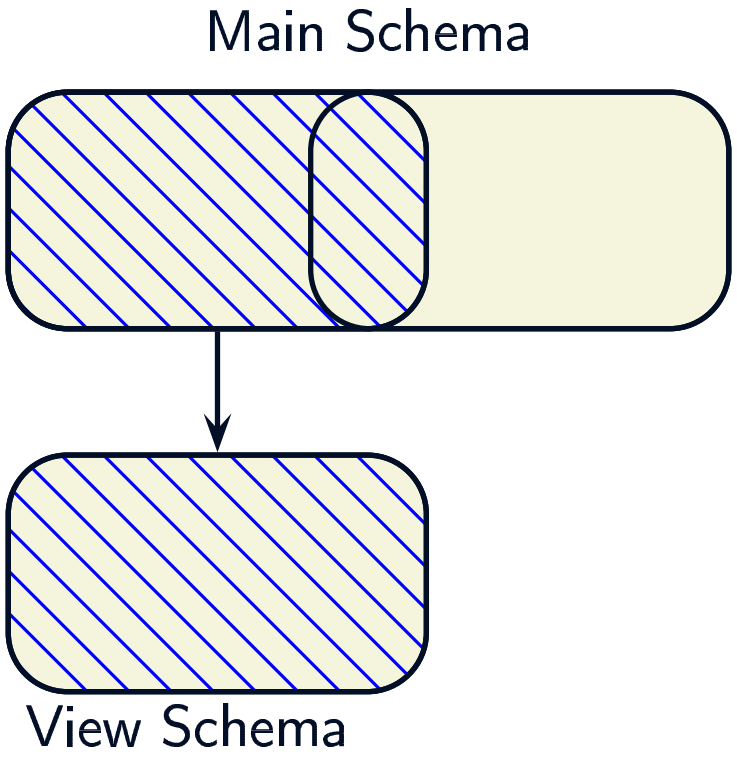
The Constant-Complement Strategy

- In the constant-complement strategy [Bancilhon and Spyratos 81], [Hegner 03], the main schema is decomposed into two *meet-complementary* views.



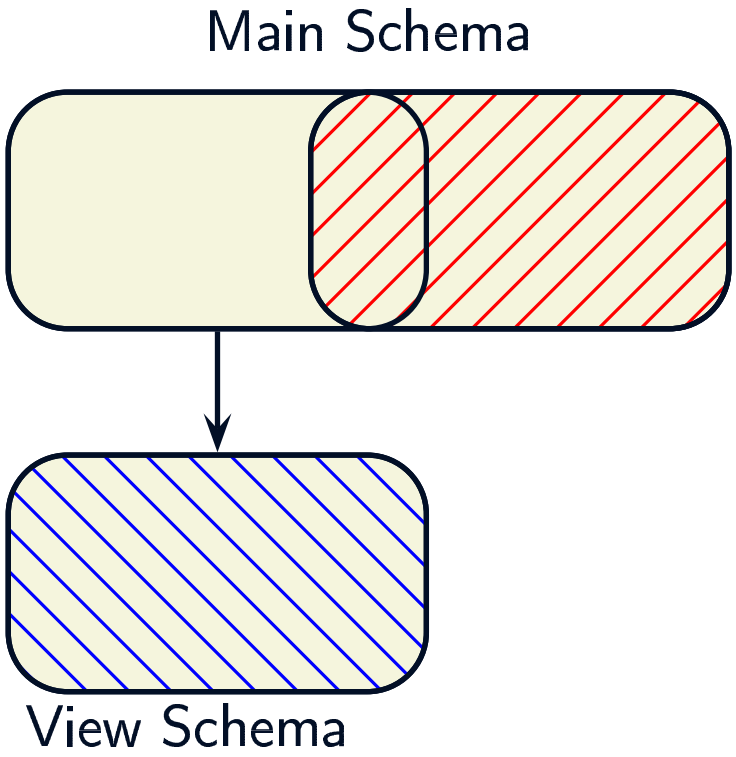
The Constant-Complement Strategy

- In the constant-complement strategy [Bancilhon and Spyratos 81], [Hegner 03], the main schema is decomposed into two *meet-complementary* views.
- One is isomorphic to the view schema and tracks its updates exactly.



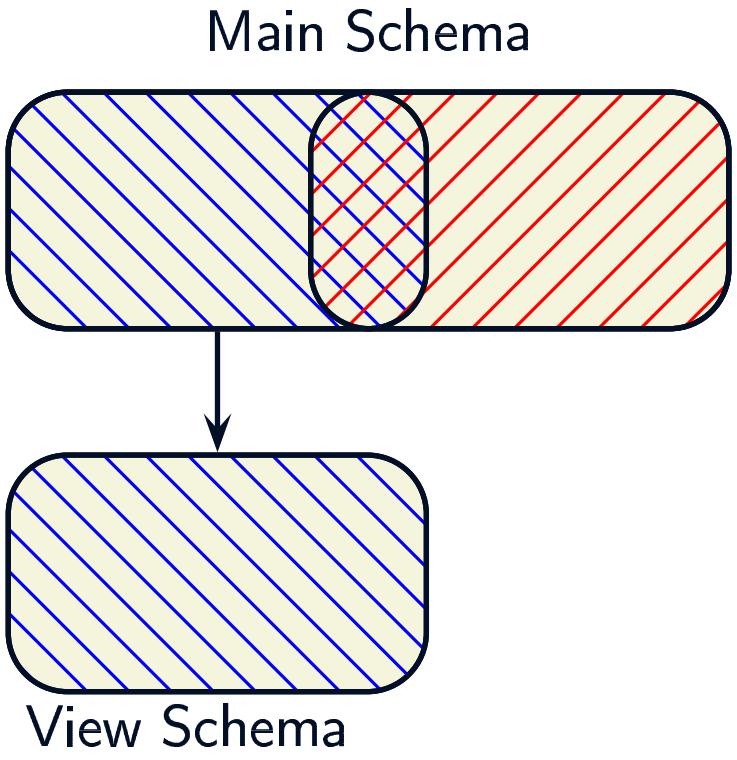
The Constant-Complement Strategy

- In the constant-complement strategy [Bancilhon and Spyratos 81], [Hegner 03], the main schema is decomposed into two *meet-complementary* views.
- One is isomorphic to the view schema and tracks its updates exactly.
- The other is held constant for all updates to the view.



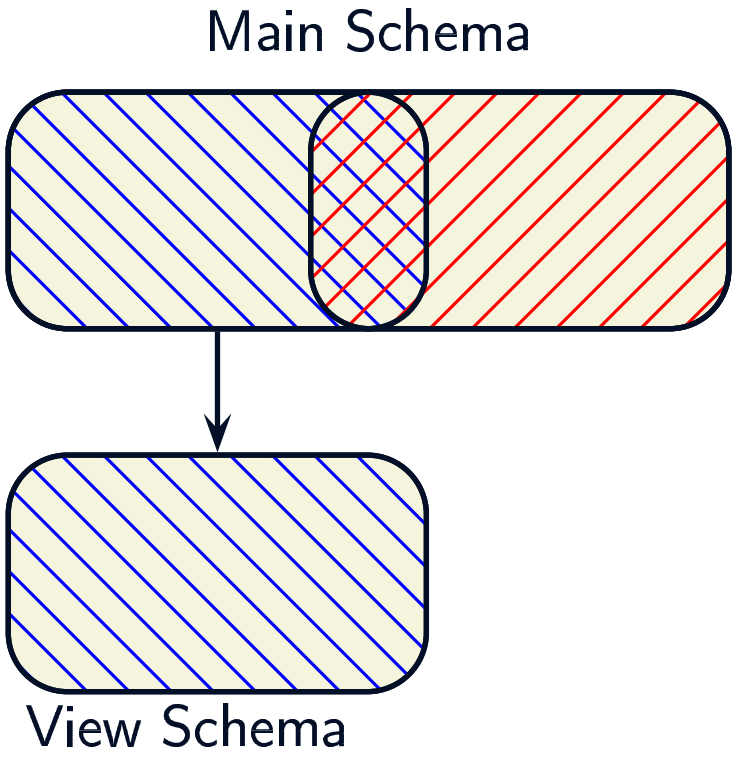
The Constant-Complement Strategy

- In the constant-complement strategy [Bancilhon and Spyratos 81], [Hegner 03], the main schema is decomposed into two *meet-complementary* views.
- One is isomorphic to the view schema and tracks its updates exactly.
- The other is held constant for all updates to the view.
- It can be shown [Hegner 03] that this strategy is precisely that which avoids all *update anomalies*.



The Constant-Complement Strategy

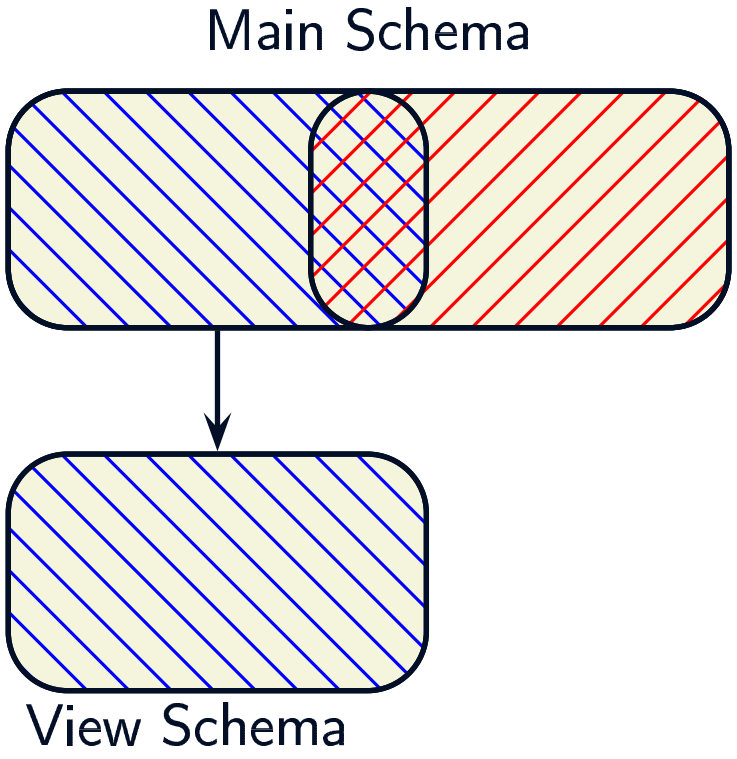
- In the constant-complement strategy [Bancilhon and Spyratos 81], [Hegner 03], the main schema is decomposed into two *meet-complementary* views.
- One is isomorphic to the view schema and tracks its updates exactly.
- The other is held constant for all updates to the view.
- It can be shown [Hegner 03] that this strategy is precisely that which avoids all *update anomalies*.



- Consequently, it is quite limited in the view updates which it allows.

The Constant-Complement Strategy

- In the constant-complement strategy [Bancilhon and Spyratos 81], [Hegner 03], the main schema is decomposed into two *meet-complementary* views.
- One is isomorphic to the view schema and tracks its updates exactly.
- The other is held constant for all updates to the view.
- It can be shown [Hegner 03] that this strategy is precisely that which avoids all *update anomalies*.

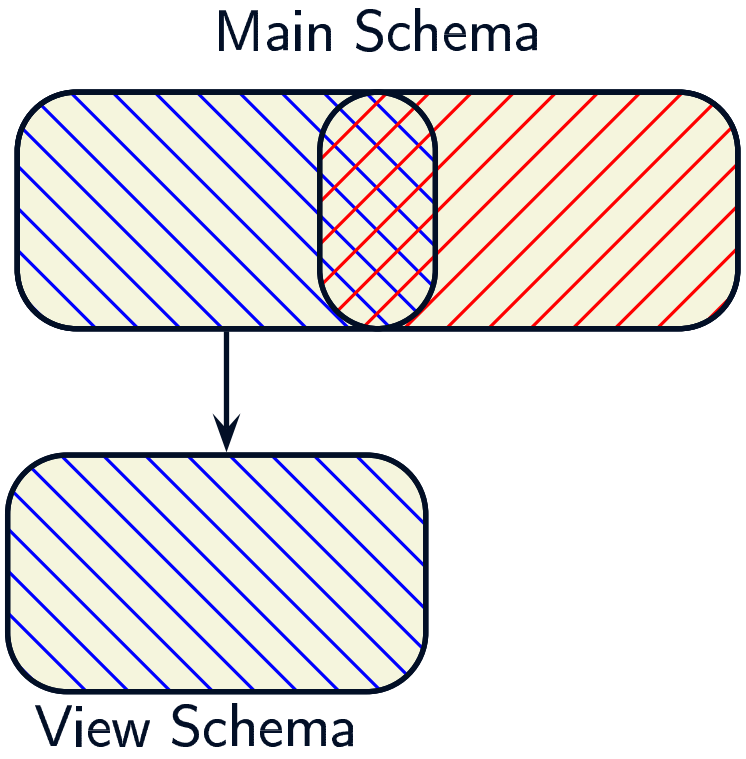


- Consequently, it is quite limited in the view updates which it allows.

Question: How can updates which are not supported by constant complement be realized?

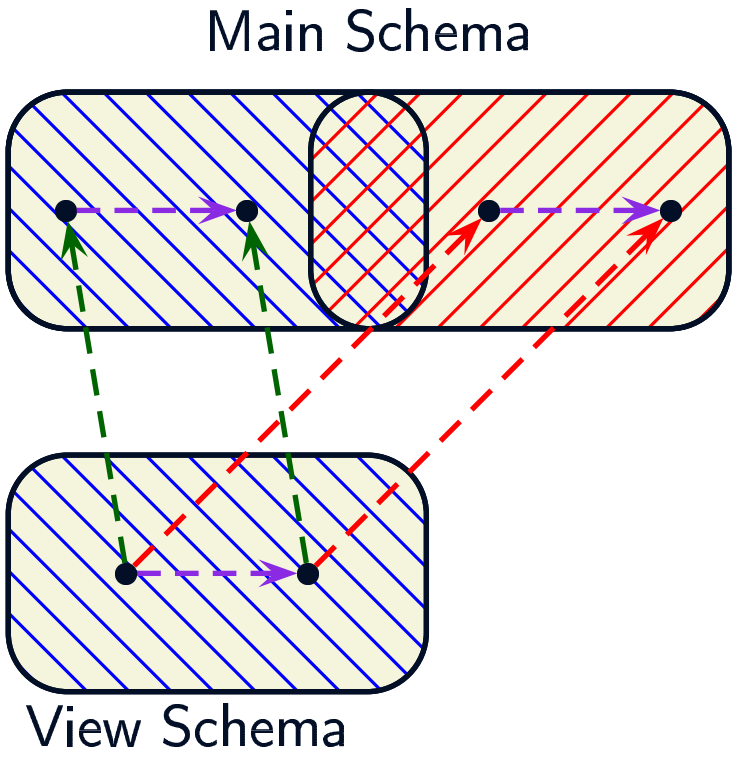
Moving Beyond the Constant-Complement Strategy

- Over the years, many extensions to the constant-complement strategy have been proposed; all share the following problems.



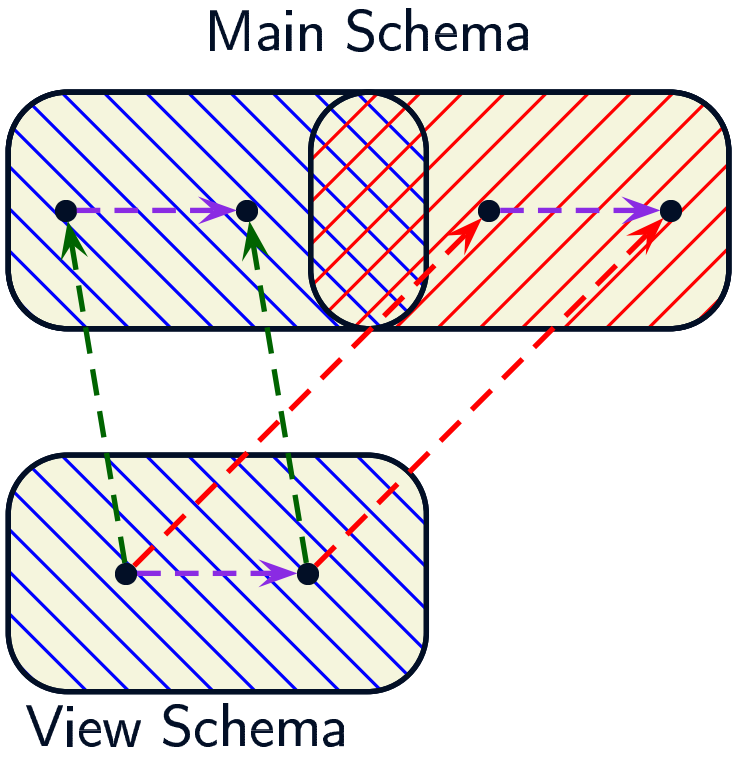
Moving Beyond the Constant-Complement Strategy

- Over the years, many extensions to the constant-complement strategy have been proposed; all share the following problems.
- Visibility problem: Part of the reflected update is not visible within the view.



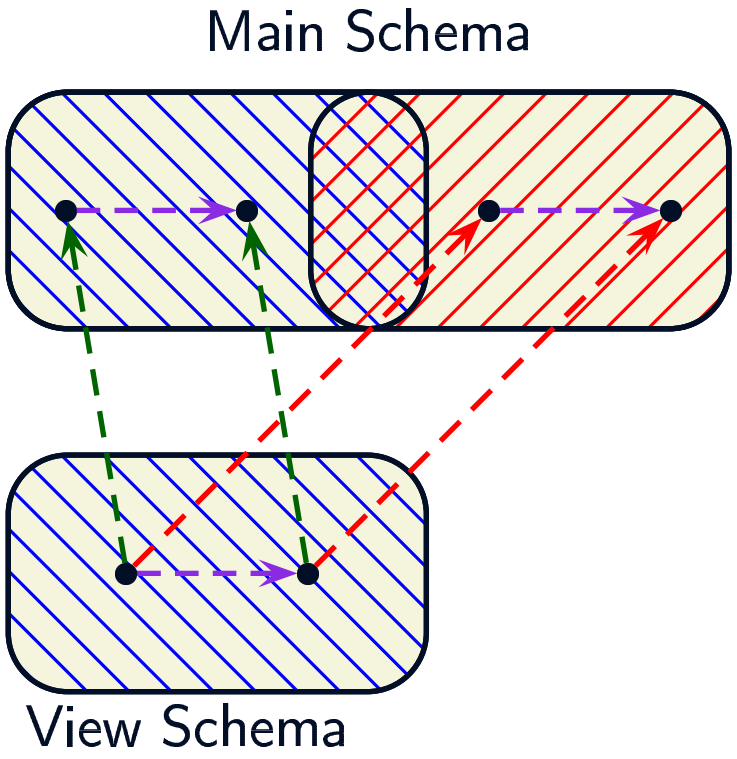
Moving Beyond the Constant-Complement Strategy

- Over the years, many extensions to the constant-complement strategy have been proposed; all share the following problems.
- Visibility problem: Part of the reflected update is not visible within the view.
- Permission problem: The user of the view lacks the necessary access privileges to effect the reflected update to the main schema.



Moving Beyond the Constant-Complement Strategy

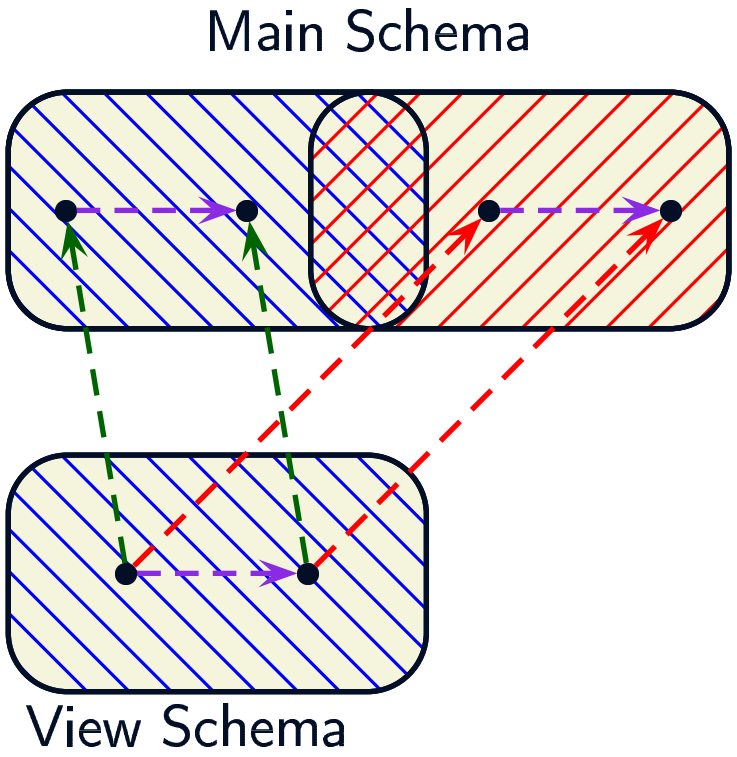
- Over the years, many extensions to the constant-complement strategy have been proposed; all share the following problems.
- Visibility problem: Part of the reflected update is not visible within the view.
- Permission problem: The user of the view lacks the necessary access privileges to effect the reflected update to the main schema.



Proposed Solution: *Update by cooperation*

Moving Beyond the Constant-Complement Strategy

- Over the years, many extensions to the constant-complement strategy have been proposed; all share the following problems.
- Visibility problem: Part of the reflected update is not visible within the view.
- Permission problem: The user of the view lacks the necessary access privileges to effect the reflected update to the main schema.

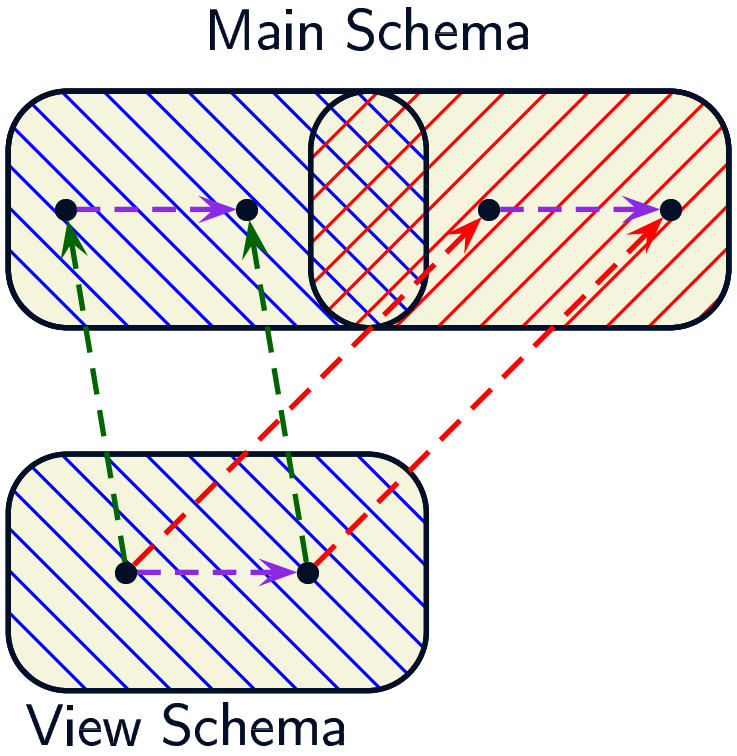


Proposed Solution: *Update by cooperation*

- The user of the view enlists the cooperation of other users to address both the visibility problem and the permission problem.

Moving Beyond the Constant-Complement Strategy

- Over the years, many extensions to the constant-complement strategy have been proposed; all share the following problems.
- Visibility problem: Part of the reflected update is not visible within the view.
- Permission problem: The user of the view lacks the necessary access privileges to effect the reflected update to the main schema.



Proposed Solution: *Update by cooperation*

- The user of the view enlists the cooperation of other users to address both the visibility problem and the permission problem.
- All users operate within the limits of their vision of the main schema and their access rights.

The Component Model of Database Schemata

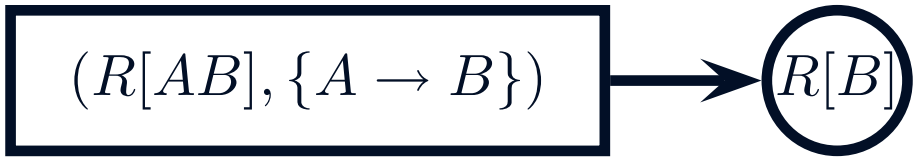
- The idea of modelling a large database schema as the interconnection of smaller *database components* has been forwarded recently by Thalheim [DKE2005].

The Component Model of Database Schemata

- The idea of modelling a large database schema as the interconnection of smaller *database components* has been forwarded recently by Thalheim [DKE2005].
- The model employed here is due to Hegner [EJC07], and is based upon *communicating views*, illustrated by a simple example below.

The Component Model of Database Schemata

- The idea of modelling a large database schema as the interconnection of smaller *database components* has been forwarded recently by Thalheim [DKE2005].
- The model employed here is due to Hegner [EJC07], and is based upon *communicating views*, illustrated by a simple example below.
- Define the component $K_{AB} = ((R[AB], \{A \to B\}), \{\Pi_B^{R[AB]}\})$

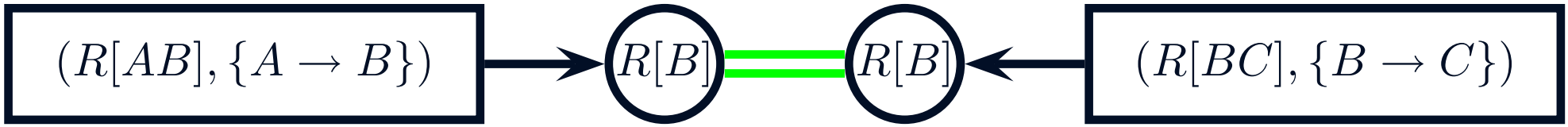


The Component Model of Database Schemata

- The idea of modelling a large database schema as the interconnection of smaller *database components* has been forwarded recently by Thalheim [DKE2005].
- The model employed here is due to Hegner [EJC07], and is based upon *communicating views*, illustrated by a simple example below.
- Define the component $K_{AB} = ((R[AB], \{A \to B\}), \{\Pi_B^{R[AB]}\})$
  and $K_{BC} = ((R[BC], \{B \to C\}), \{\Pi_B^{R[BC]}\})$.

The Component Model of Database Schemata

- The idea of modelling a large database schema as the interconnection of smaller *database components* has been forwarded recently by Thalheim [DKE2005].
- The model employed here is due to Hegner [EJC07], and is based upon *communicating views*, illustrated by a simple example below.
- Define the component $K_{AB} = ((R[AB], \{A \to B\}), \{\Pi_B^{R[AB]}\})$
  and $K_{BC} = ((R[BC], \{B \to C\}), \{\Pi_B^{R[BC]}\})$.
- Connecting the ports of these two components results in a combination which is isomorphic to $(R[ABC], \{A \to B, B \to C\})$.

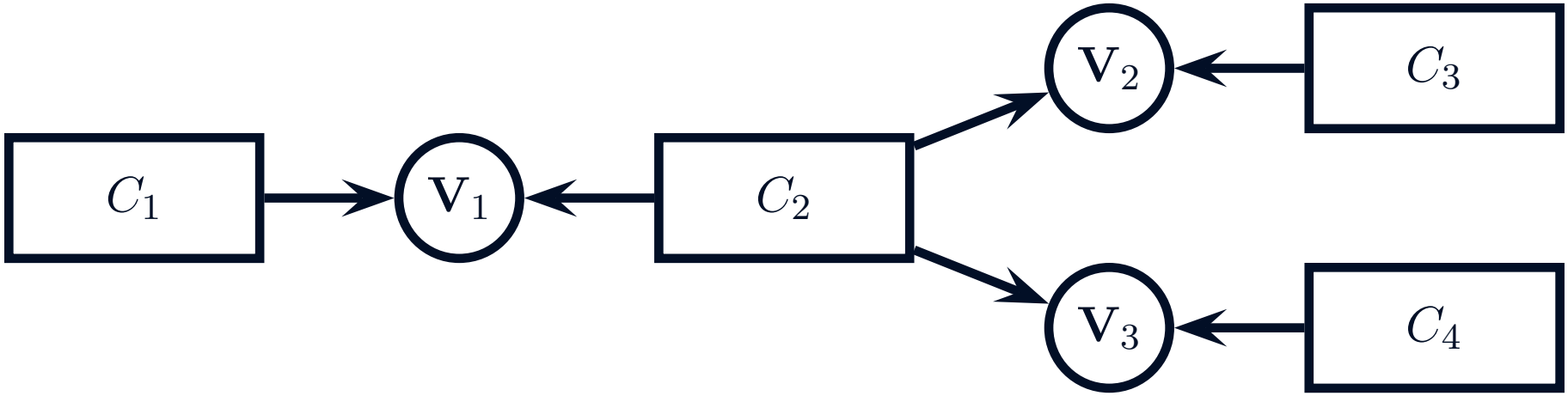


The Component Model of Database Schemata

- The idea of modelling a large database schema as the interconnection of smaller *database components* has been forwarded recently by Thalheim [DKE2005].
- The model employed here is due to Hegner [EJC07], and is based upon *communicating views*, illustrated by a simple example below.
- Define the component $K_{AB} = ((R[AB], \{A \to B\}), \{\Pi_B^{R[AB]}\})$
  and $K_{BC} = ((R[BC], \{B \to C\}), \{\Pi_B^{R[BC]}\})$.
- Connecting the ports of these two components results in a combination which is isomorphic to $(R[ABC], \{A \to B, B \to C\})$.

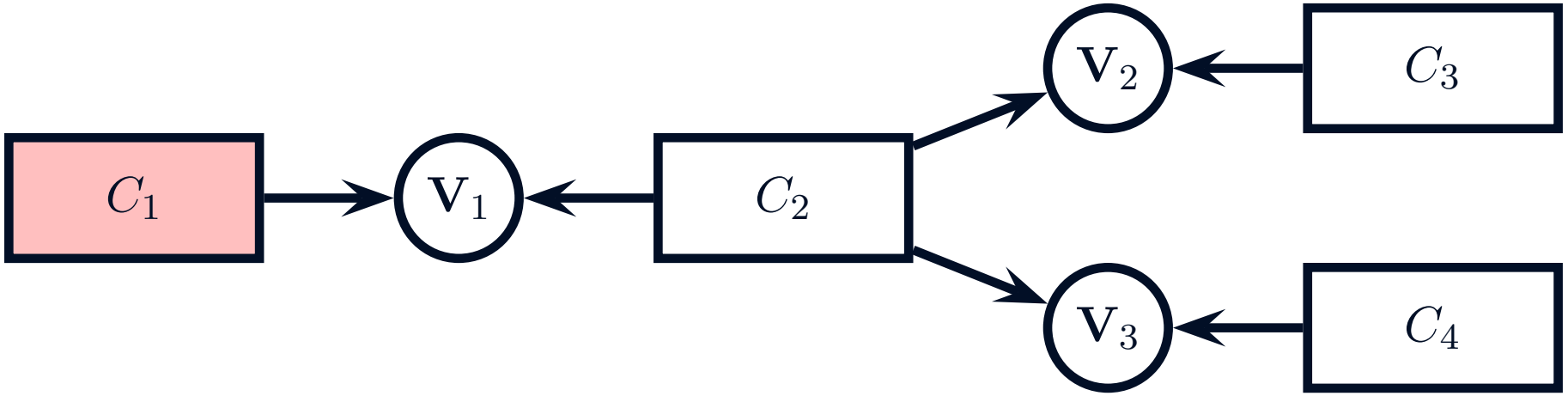
- This recaptures lossless and dependency-preserving decomposition, but as a *composition* rather than as a decomposition.

The Propagation of Updates through Components



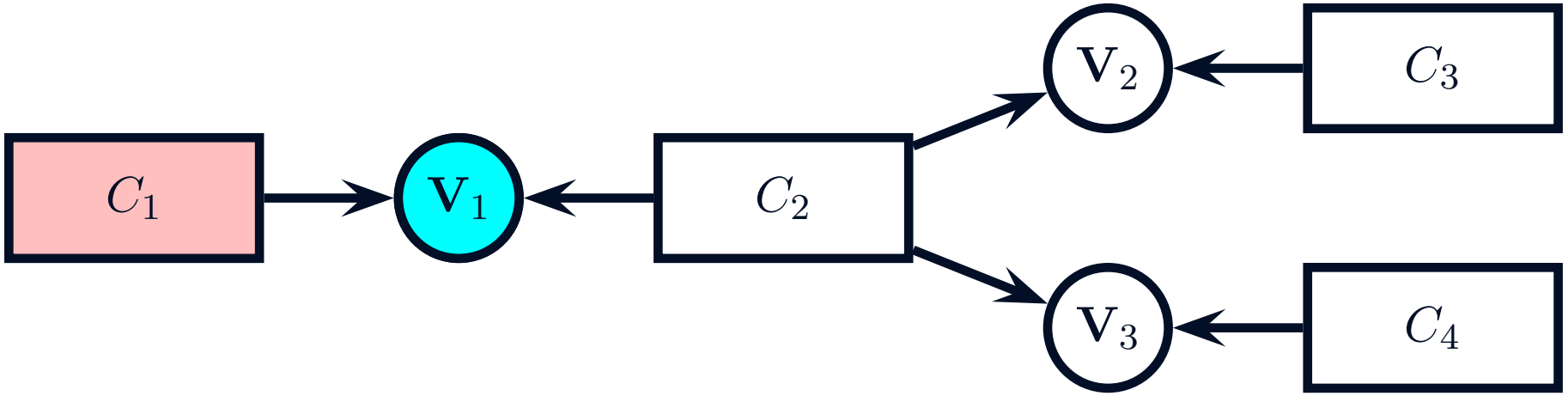
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.



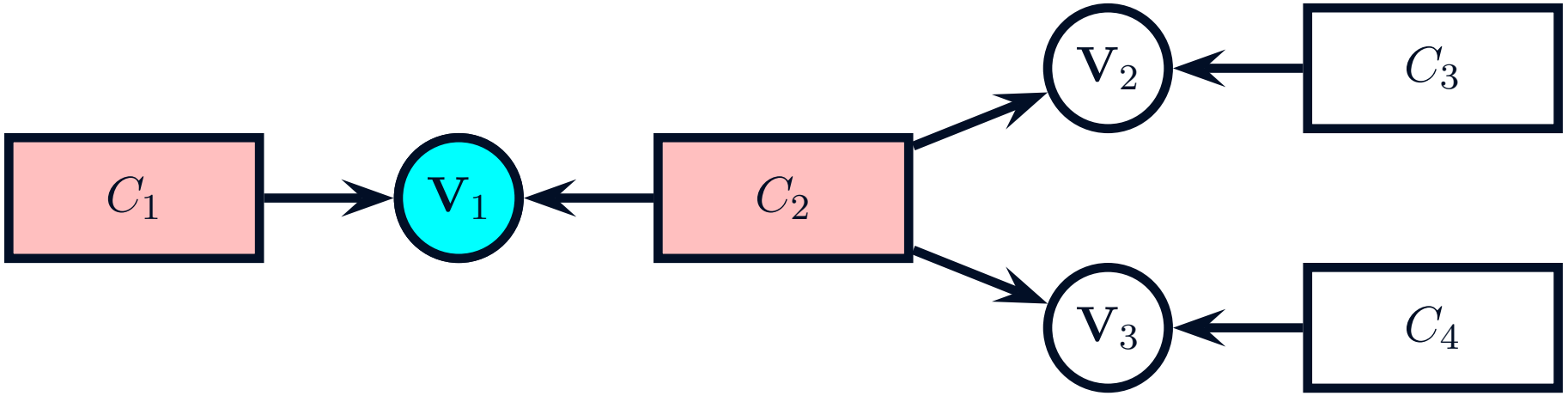
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.



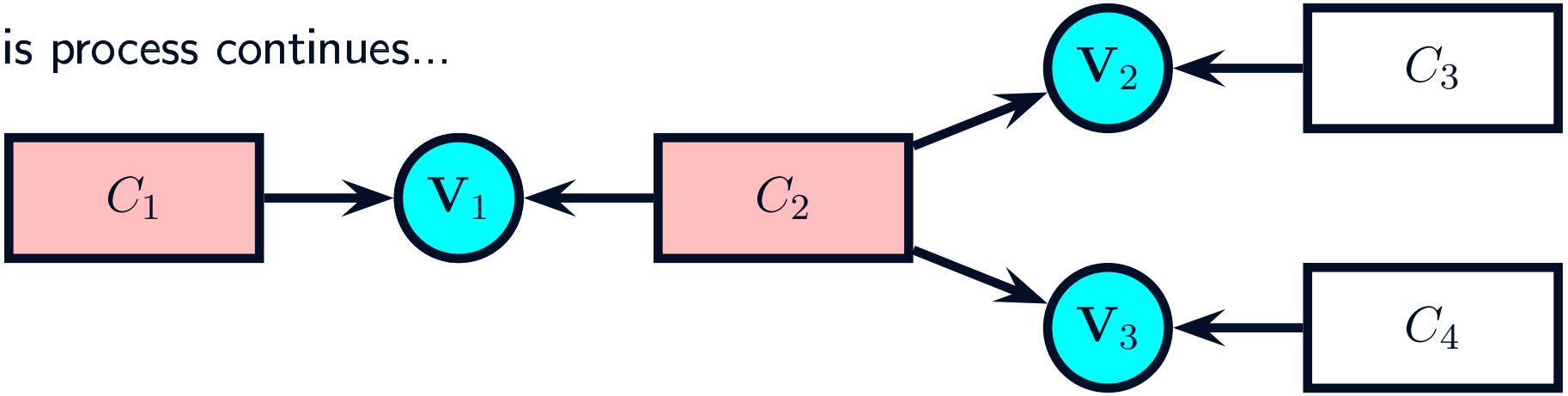
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.



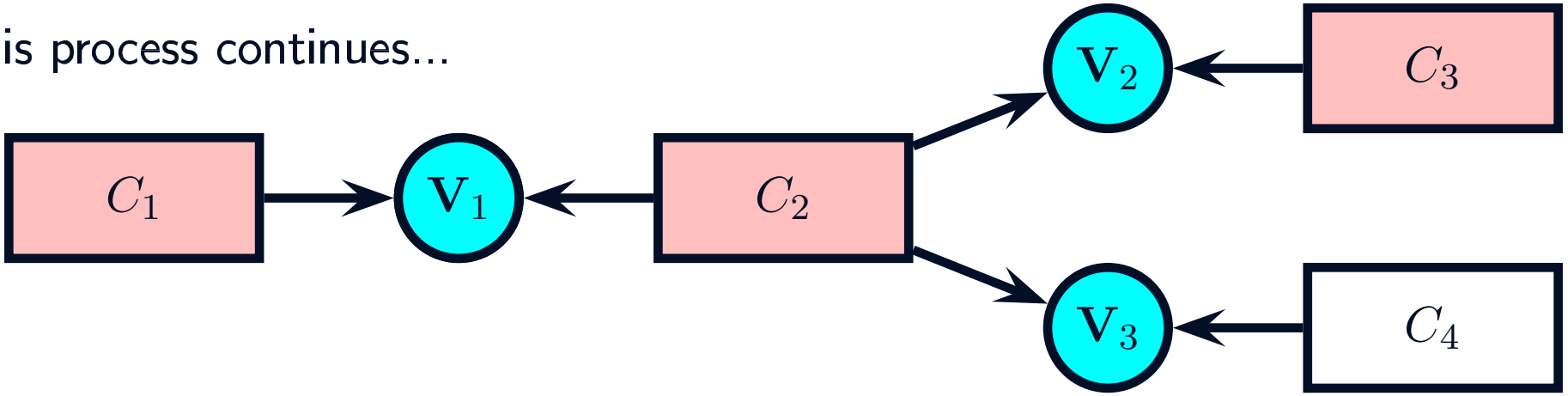
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



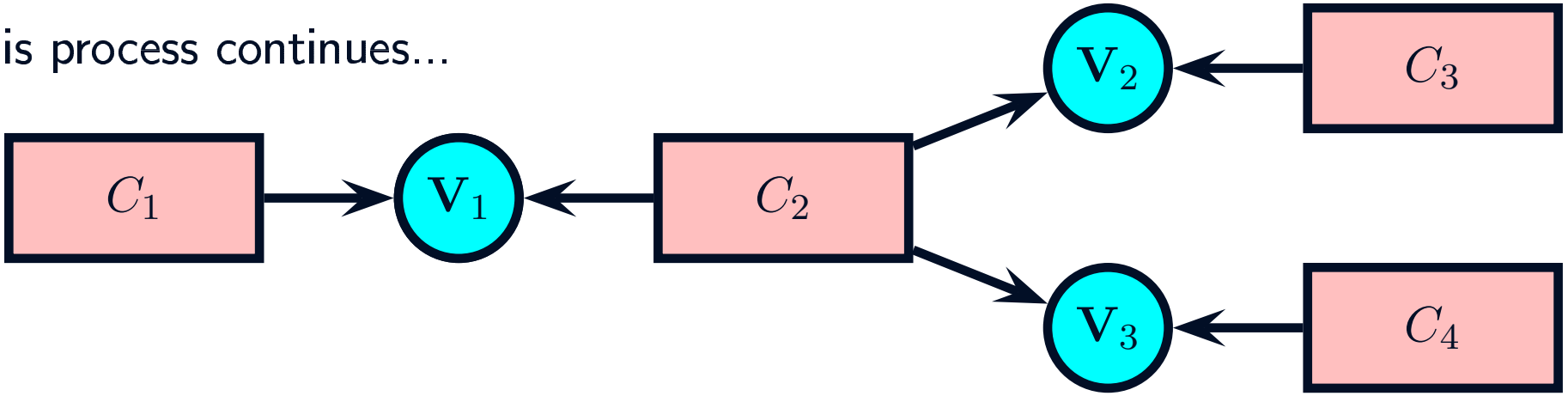
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



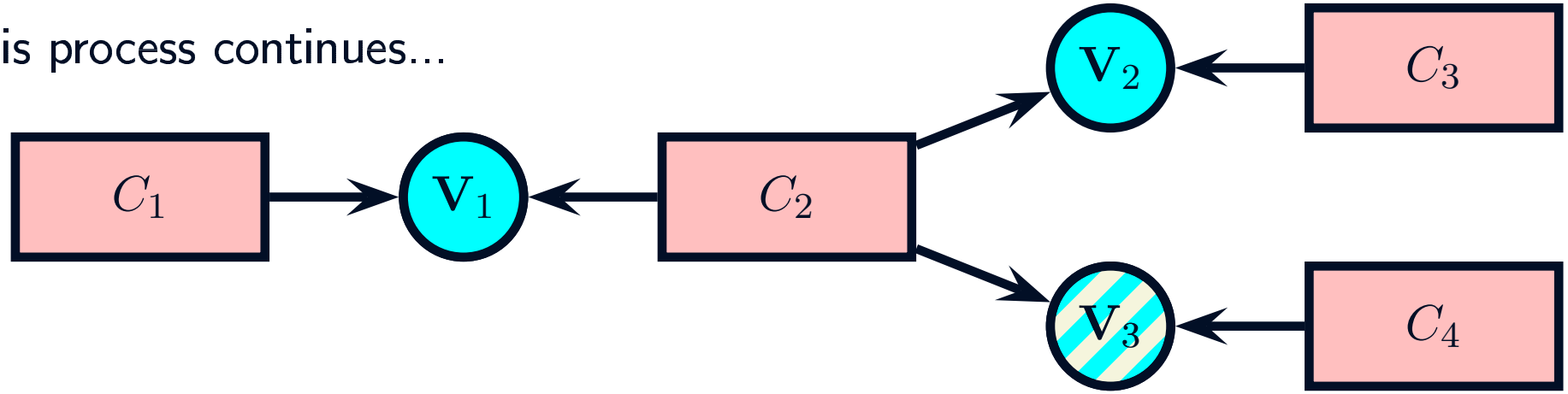
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



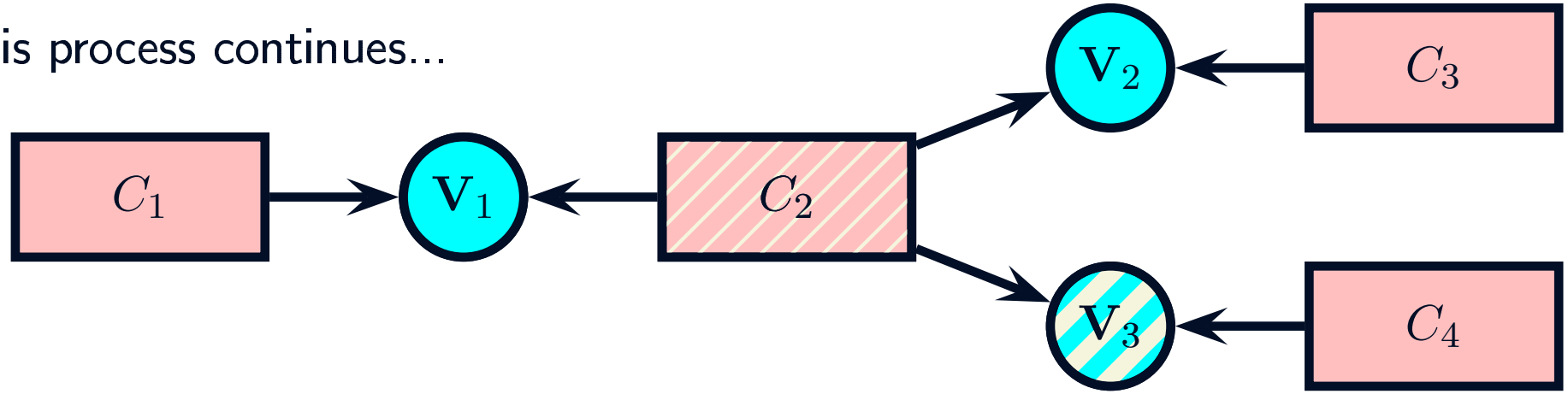
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



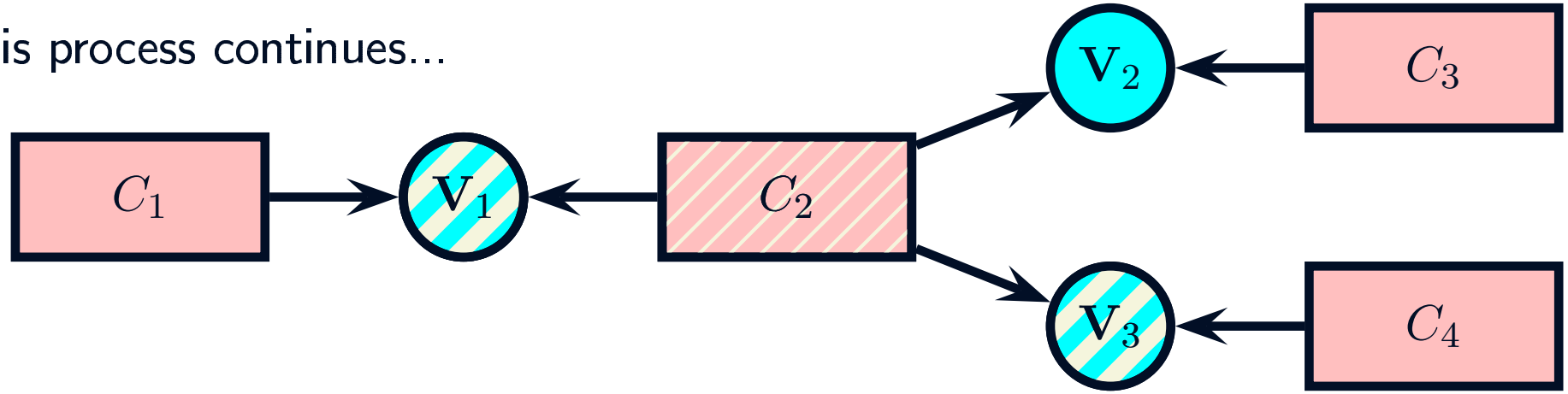
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



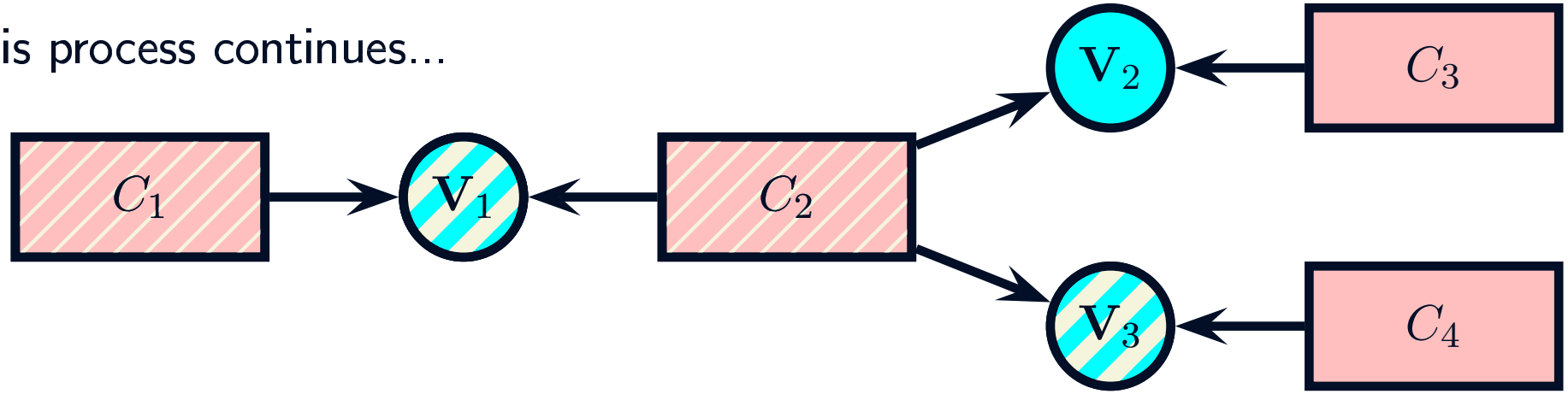
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



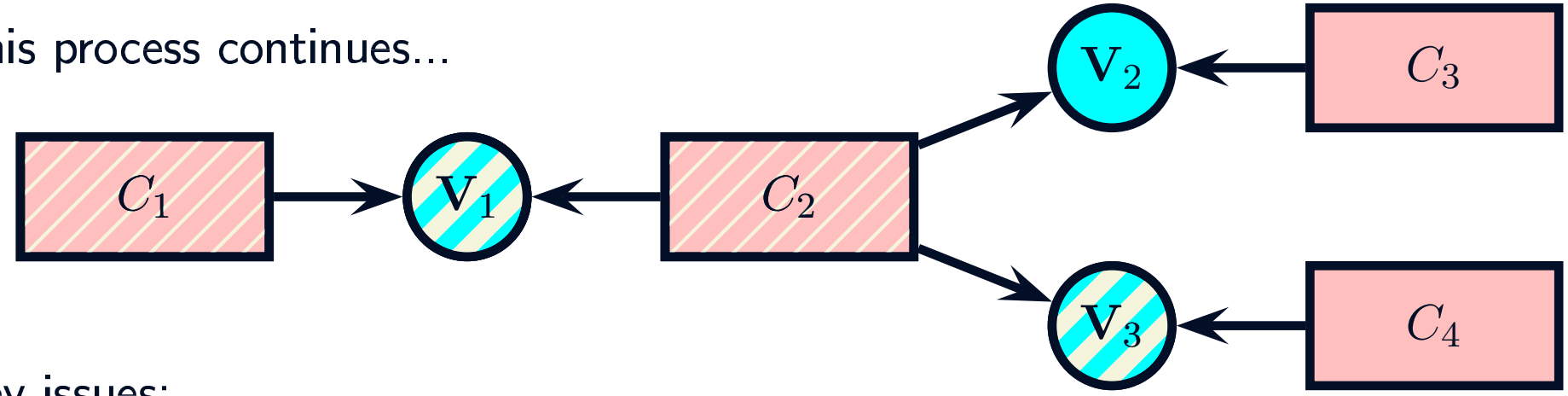
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



The Propagation of Updates through Components

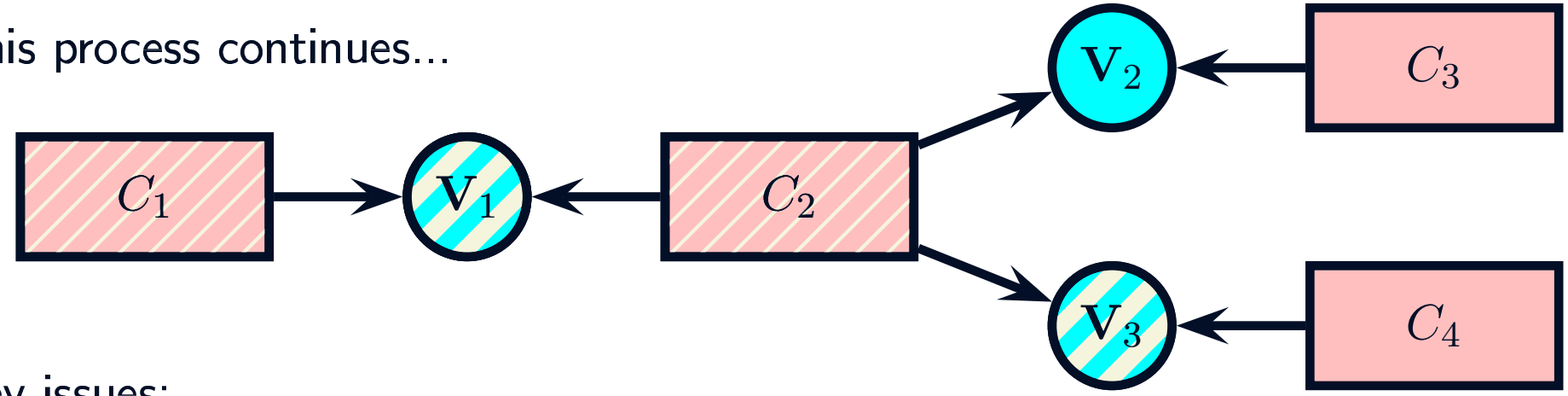
- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



- Key issues:

The Propagation of Updates through Components

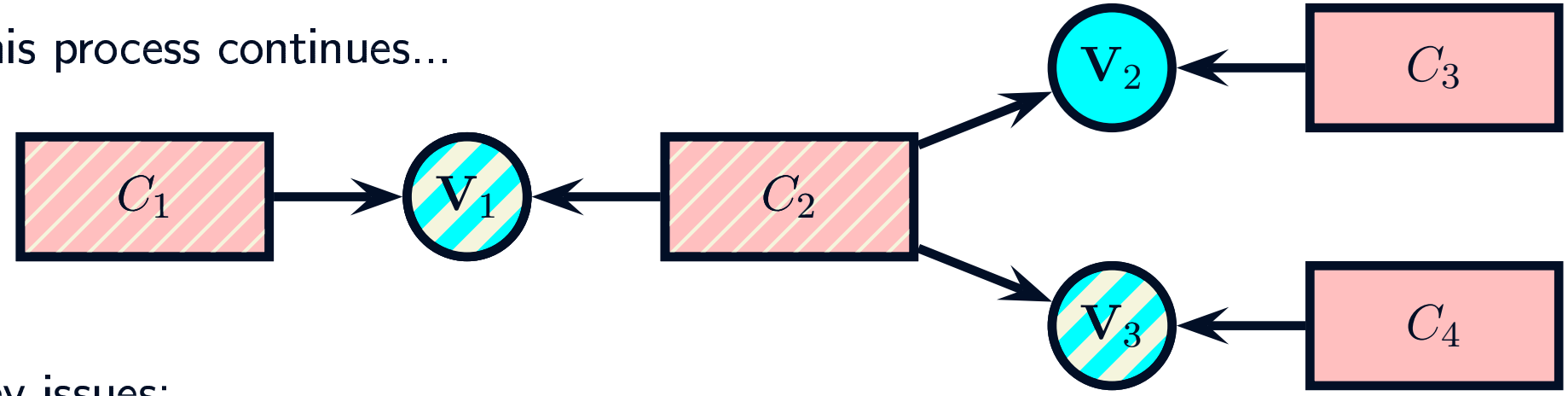
- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



- Key issues:
  - *Database consistency*: Actual database update must be deferred until the negotiation process is complete.

The Propagation of Updates through Components

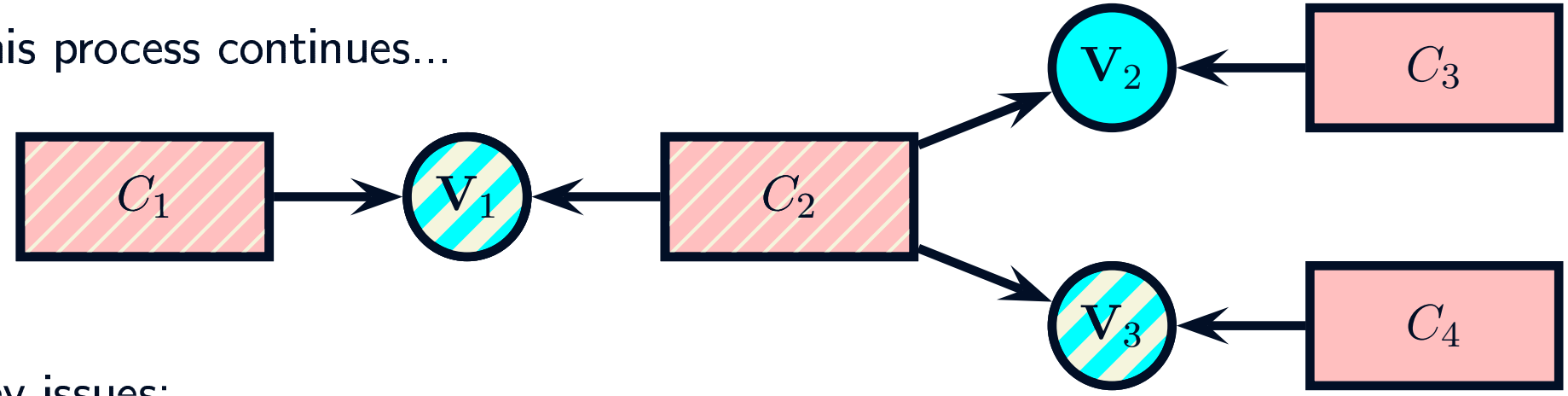
- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...



- Key issues:
  - *Database consistency*: Actual database update must be deferred until the negotiation process is complete.
  - *Termination*: The negotiation process must not go on endlessly.

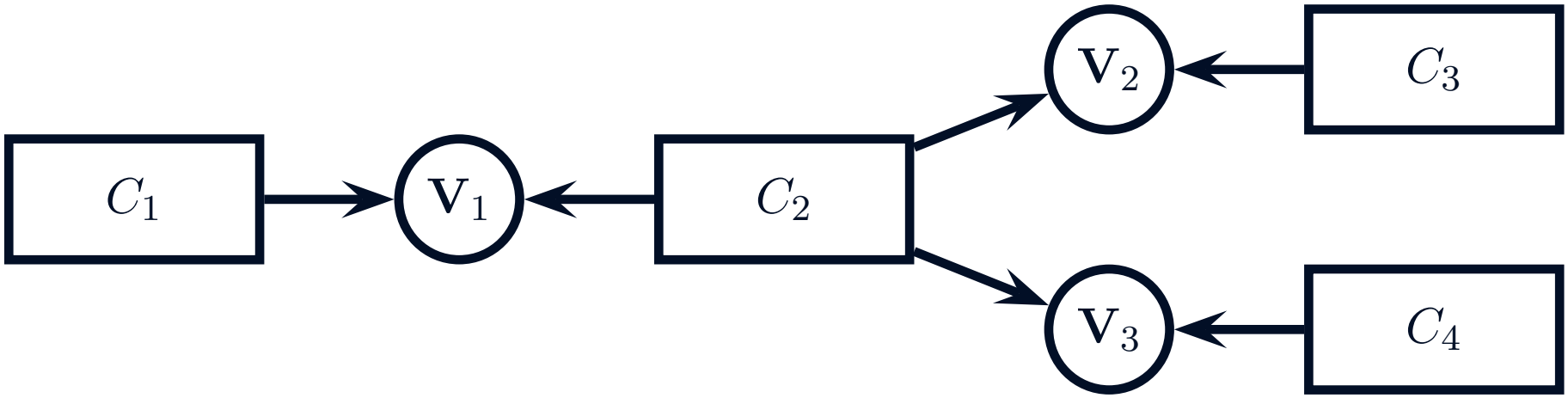
The Propagation of Updates through Components

- Suppose that an update to the schema of component C_1 is proposed.
- This may require an update to the port schema $\mathbf{V}_1$ as well.
- In turn, this will require a *lifting* of that update to C_2.
- This process continues...

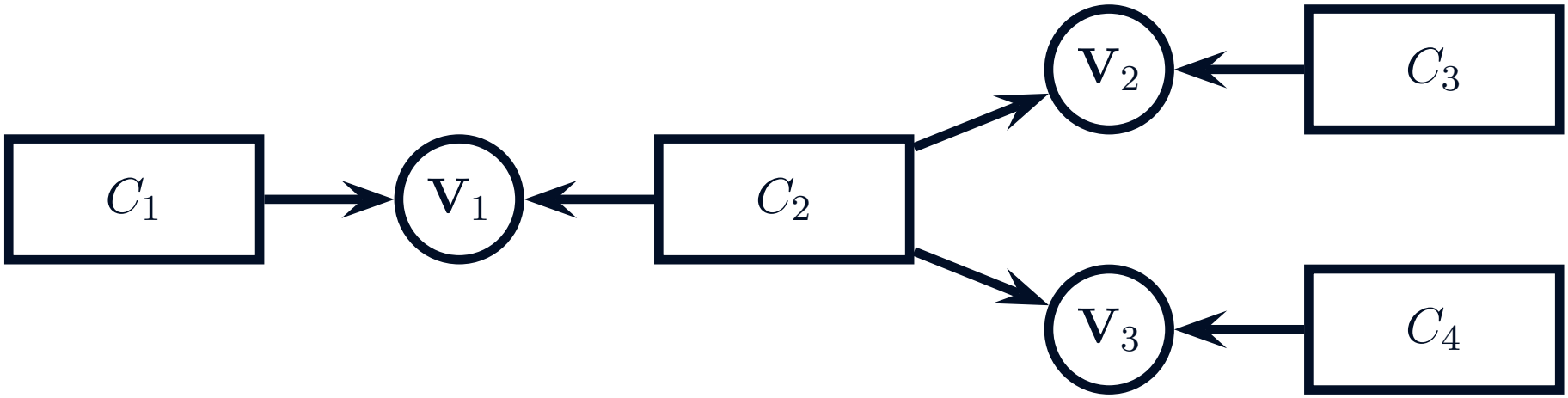


- Key issues:
  - *Database consistency*: Actual database update must be deferred until the negotiation process is complete.
  - *Termination*: The negotiation process must not go on endlessly.
- An architecture for the support of such *cooperative updates* is needed.

The Architecture of Cooperative Update Management

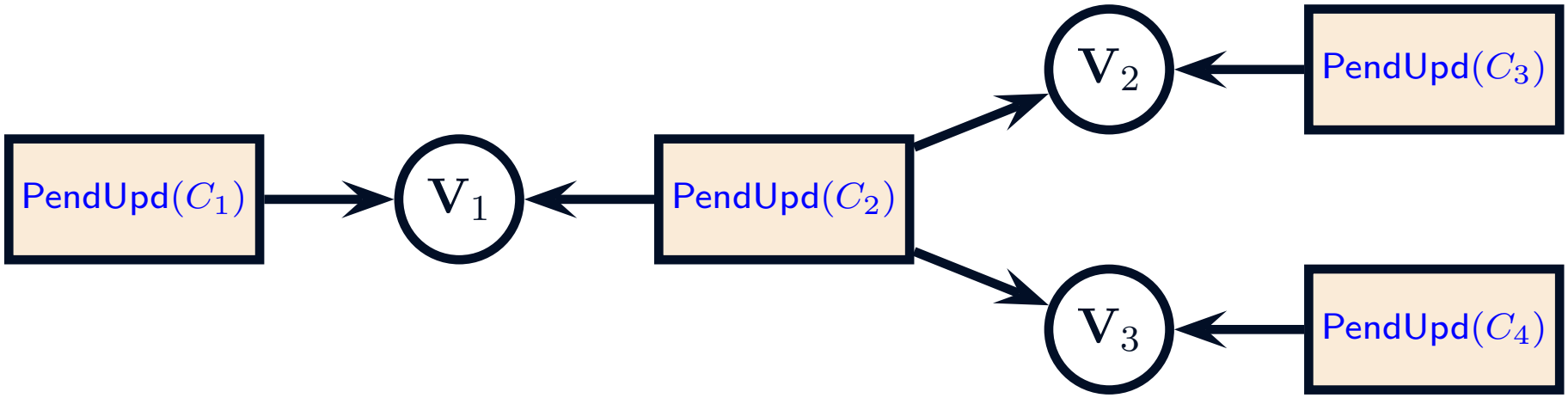


The Architecture of Cooperative Update Management



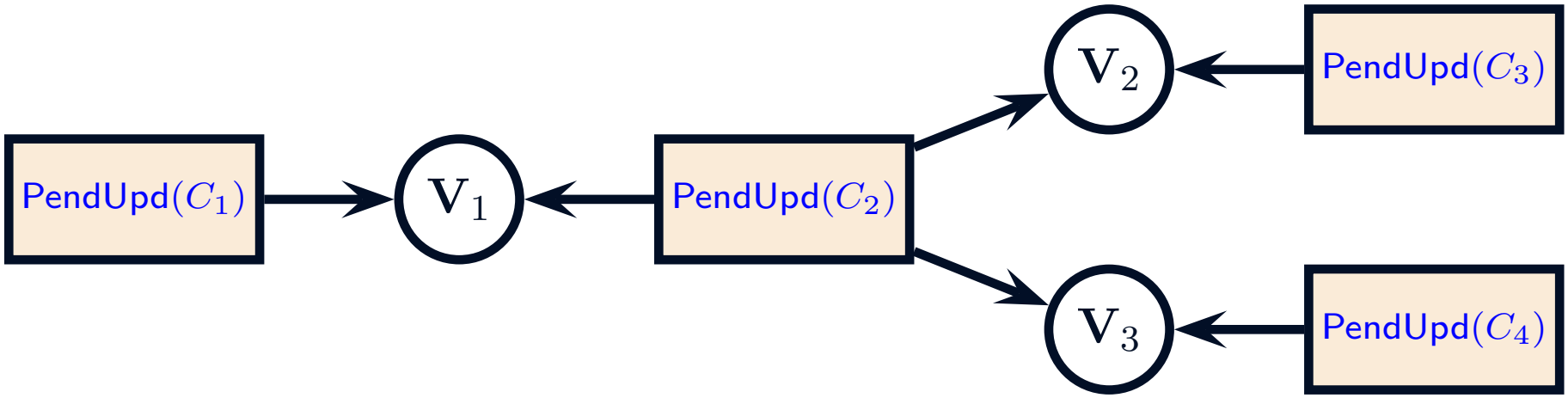
- To each component C_i corresponds a *pending-update register* PendUpd(C_i).

The Architecture of Cooperative Update Management



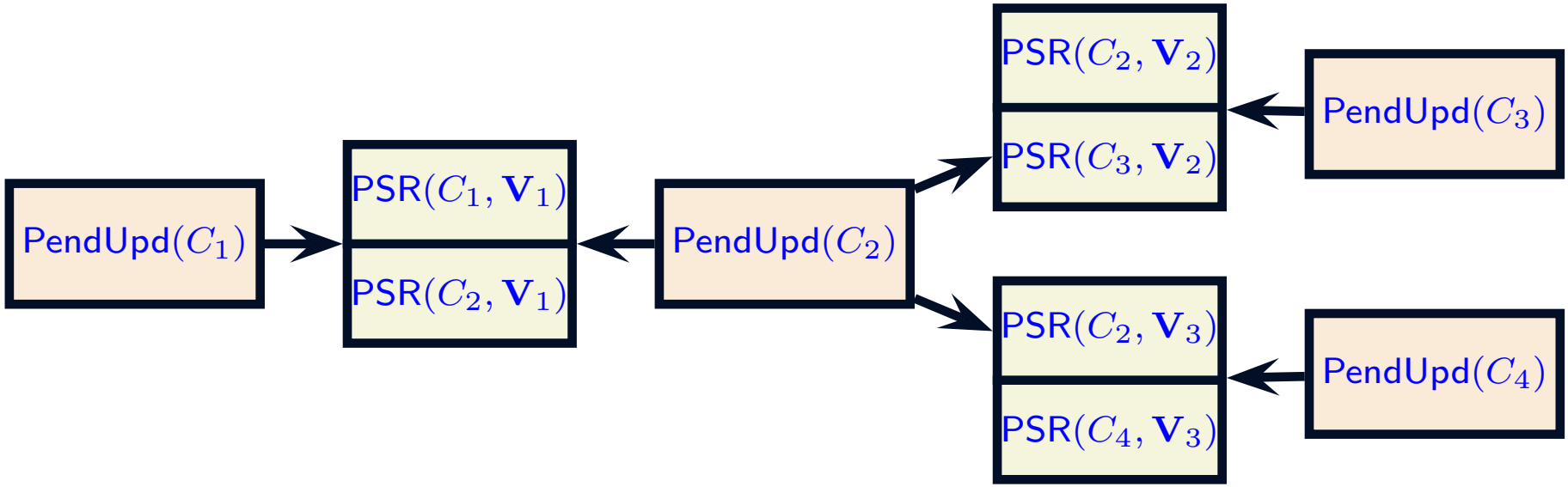
- To each component C_i corresponds a *pending-update register* PendUpd(C_i).

The Architecture of Cooperative Update Management



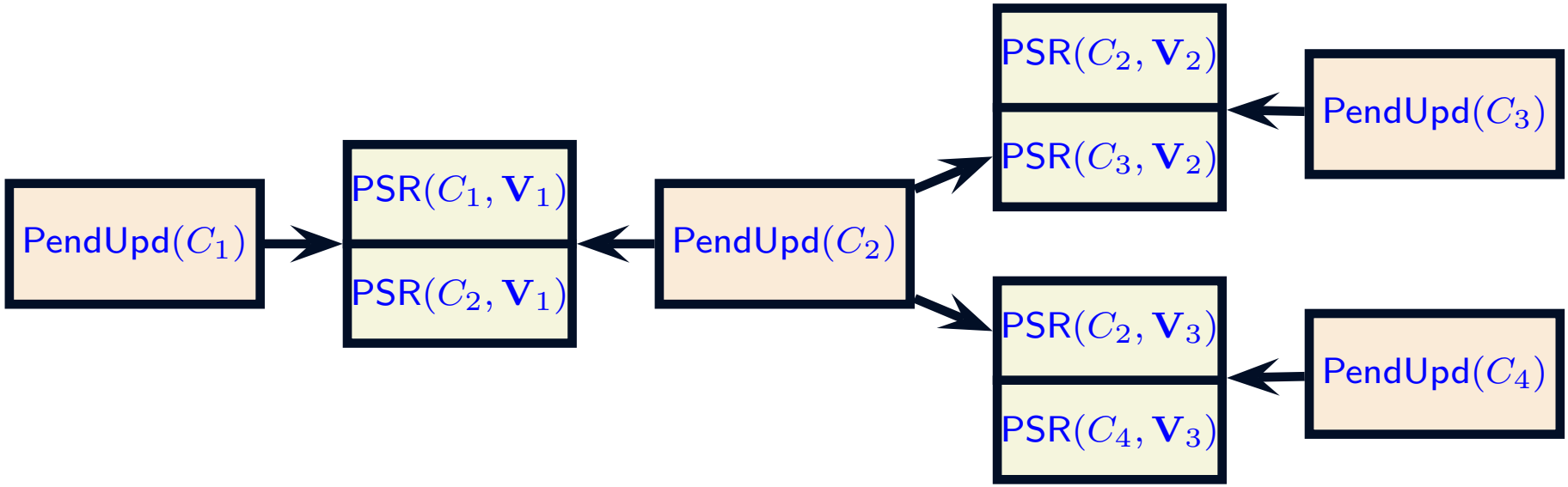
- To each component C_i corresponds a *pending-update register* PendUpd(C_i).
- To each view schema $\mathbf{V}_i$ is associated a *port-status register* PSR($C_j, \mathbf{V}_i$) for each component C_j which is connected to it.

The Architecture of Cooperative Update Management



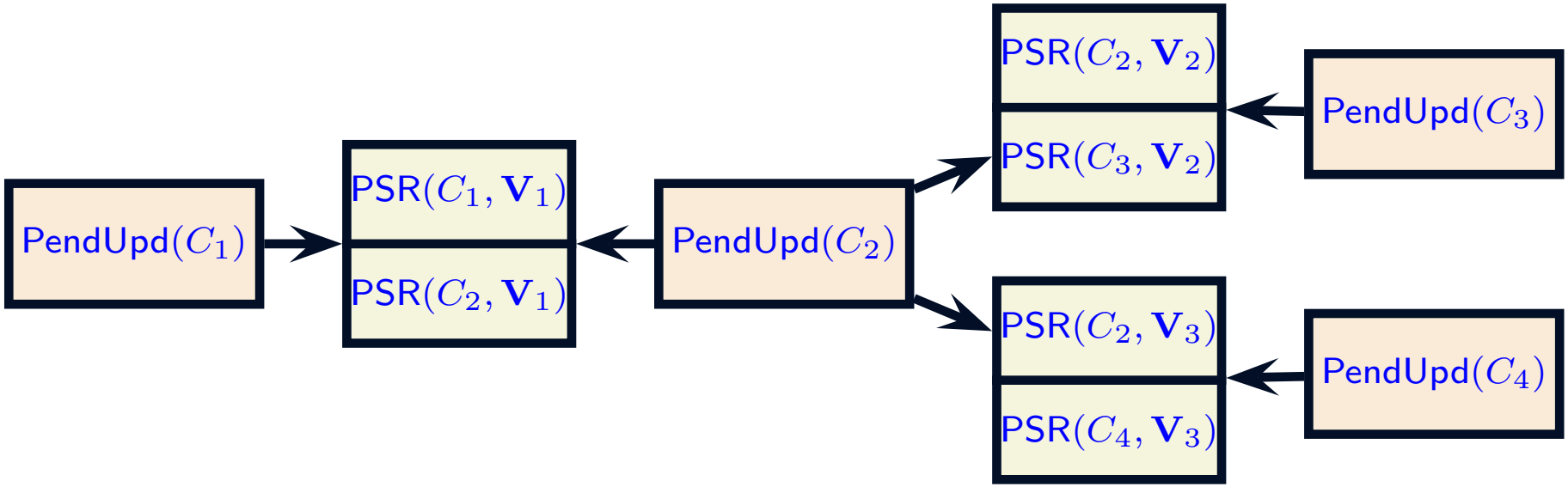
- To each component C_i corresponds a *pending-update register* PendUpd(C_i).
- To each view schema $\mathbf{V}_i$ is associated a *port-status register* PSR(C_j, $\mathbf{V}_i$) for each component C_j which is connected to it.

The Architecture of Cooperative Update Management



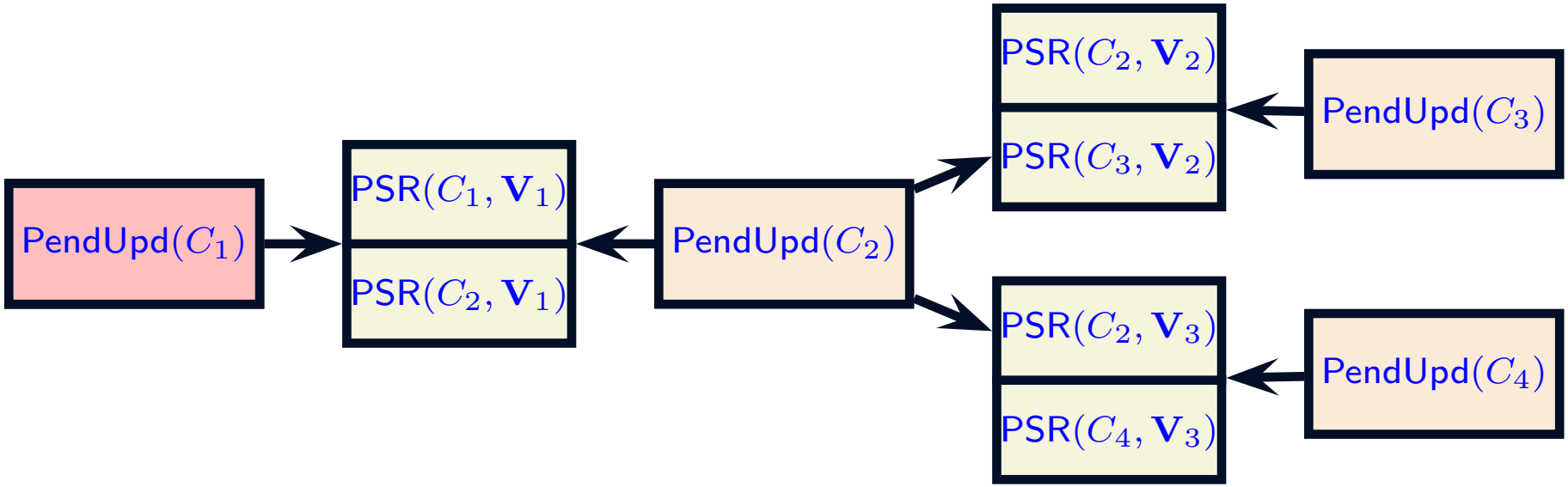
- To each component C_i corresponds a *pending-update register* PendUpd(C_i).
- To each view schema $\mathbf{V}_i$ is associated a *port-status register* PSR(C_j, $\mathbf{V}_i$) for each component C_j which is connected to it.
- These additional registers are part of the control structure, and are in addition to the database itself.

Operation of Cooperative Update Management



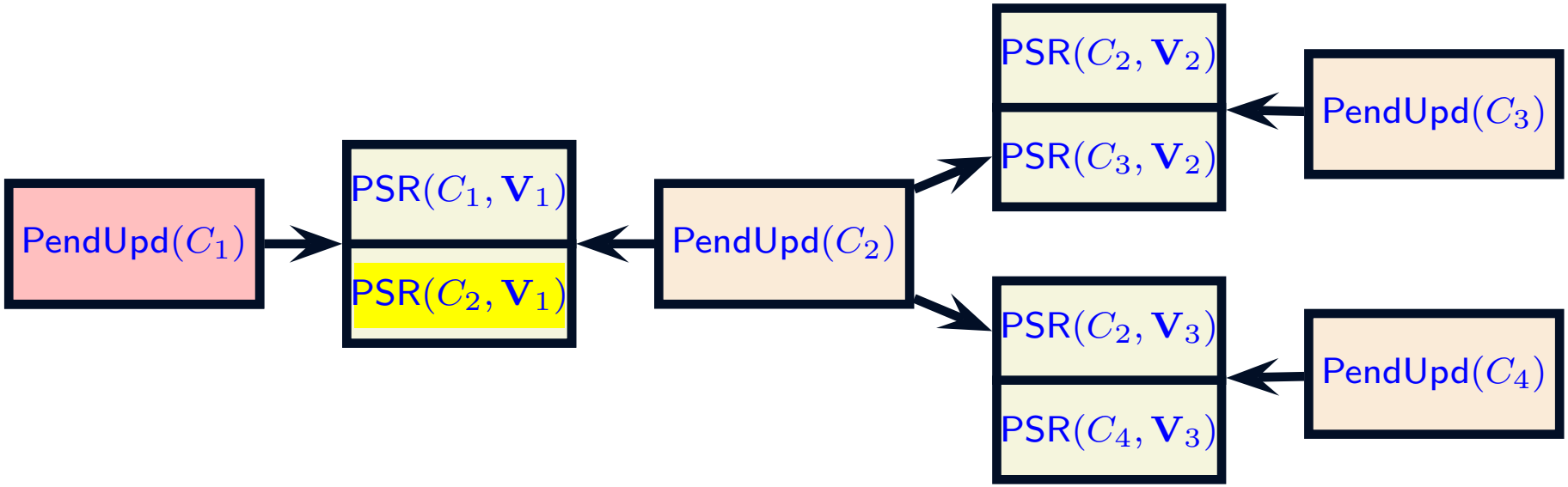
- All port-status registers are initially null.

Operation of Cooperative Update Management



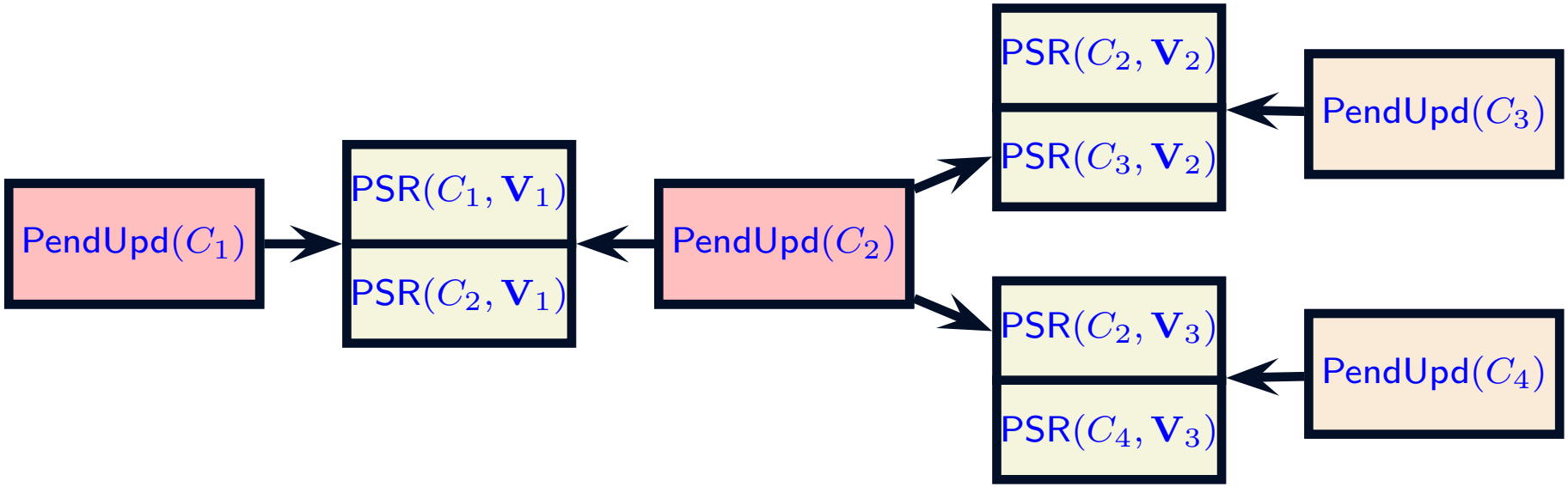
- All port-status registers are initially null.
- An update to a component schema

Operation of Cooperative Update Management



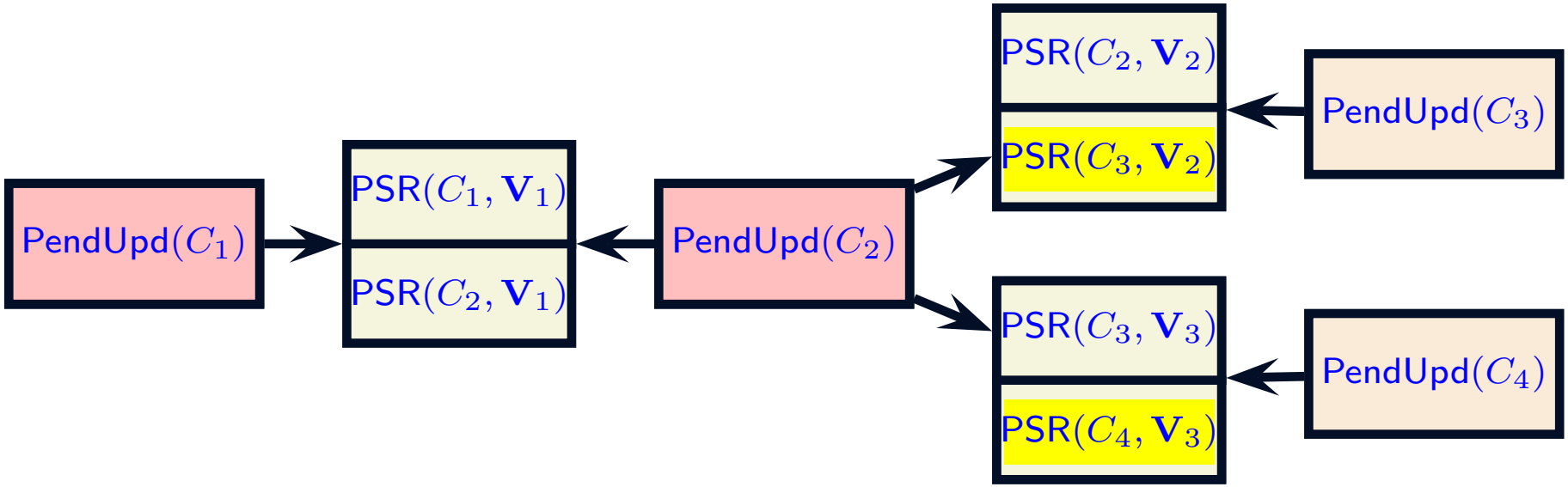
- All port-status registers are initially null.
- An update to a component schema places the corresponding projection into the port status registers of its neighbors.

Operation of Cooperative Update Management



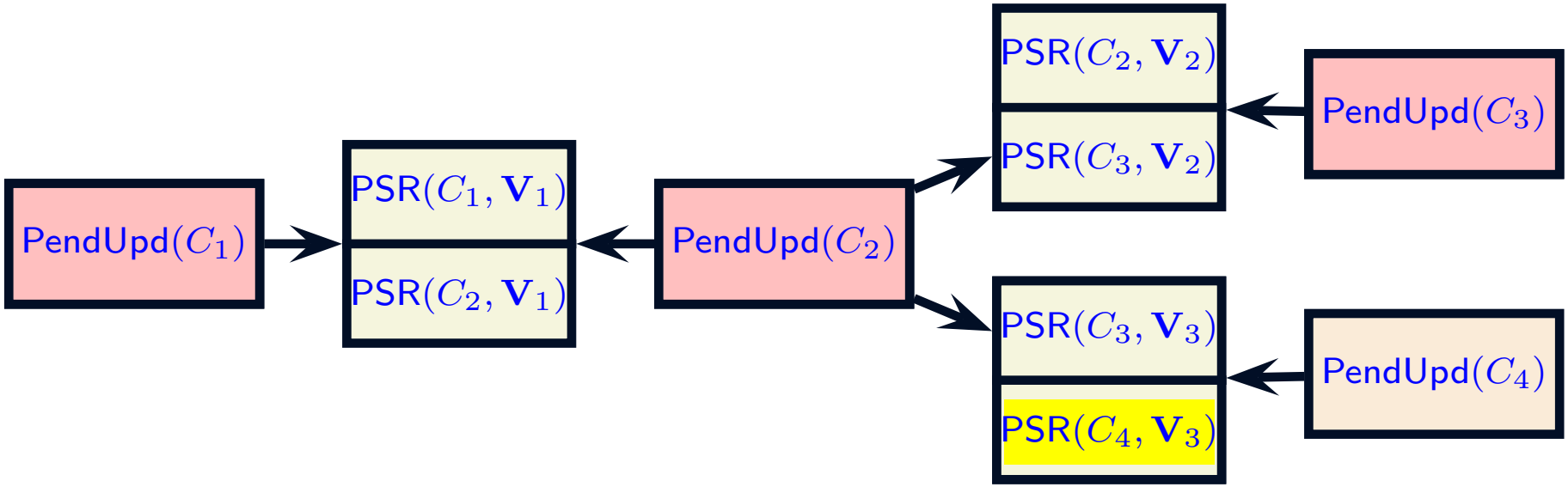
- All port-status registers are initially null.
- An update to a component schema places the corresponding projection into the port status registers of its neighbors.
- The neighbor then identifies a suitable *lifting* of the view state in the port-status register to its schema, and resets that port-status register to null.

Operation of Cooperative Update Management



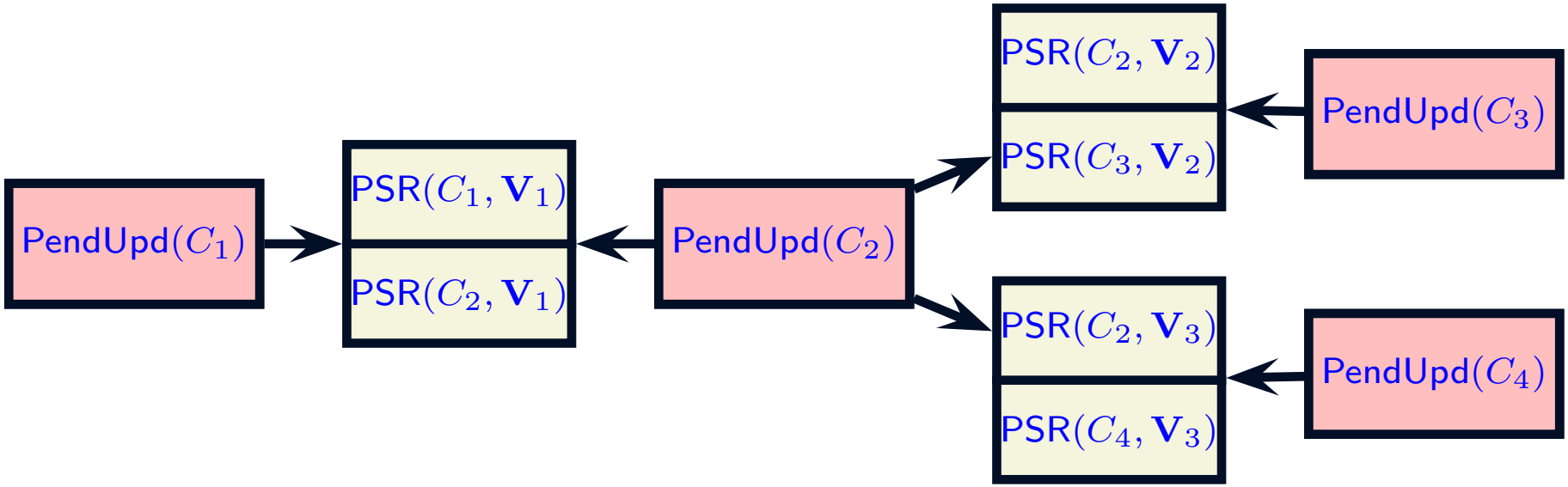
- All port-status registers are initially null.
- An update to a component schema places the corresponding projection into the port status registers of its neighbors.
- The neighbor then identifies a suitable *lifting* of the view state in the port-status register to its schema, and resets that port-status register to null.
- The process repeats, and is nondeterministic.

Operation of Cooperative Update Management



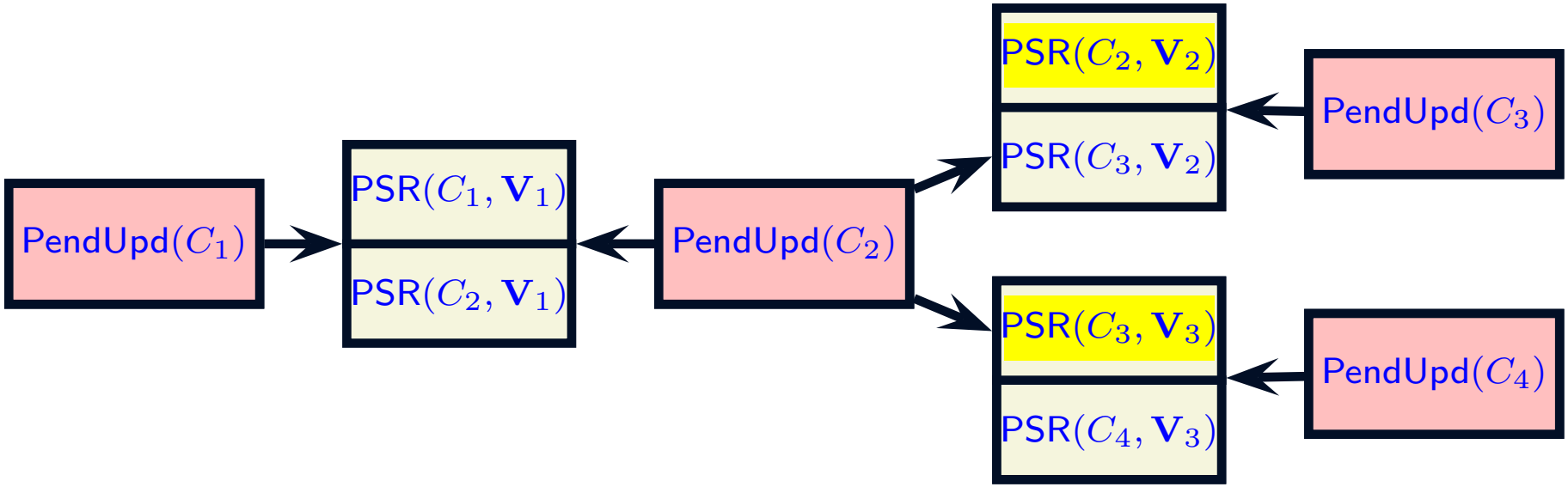
- All port-status registers are initially null.
- An update to a component schema places the corresponding projection into the port status registers of its neighbors.
- The neighbor then identifies a suitable *lifting* of the view state in the port-status register to its schema, and resets that port-status register to null.
- The process repeats, and is nondeterministic.

Operation of Cooperative Update Management



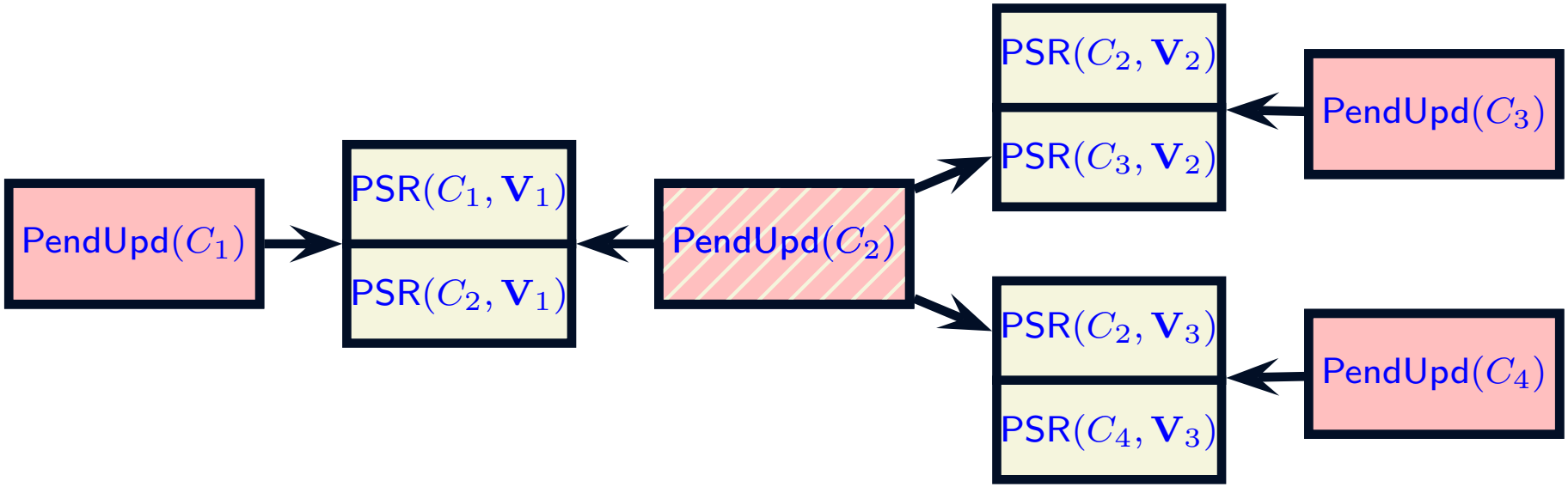
- All port-status registers are initially null.
- An update to a component schema places the corresponding projection into the port status registers of its neighbors.
- The neighbor then identifies a suitable *lifting* of the view state in the port-status register to its schema, and resets that port-status register to null.
- The process repeats, and is nondeterministic.

Operation of Cooperative Update Management



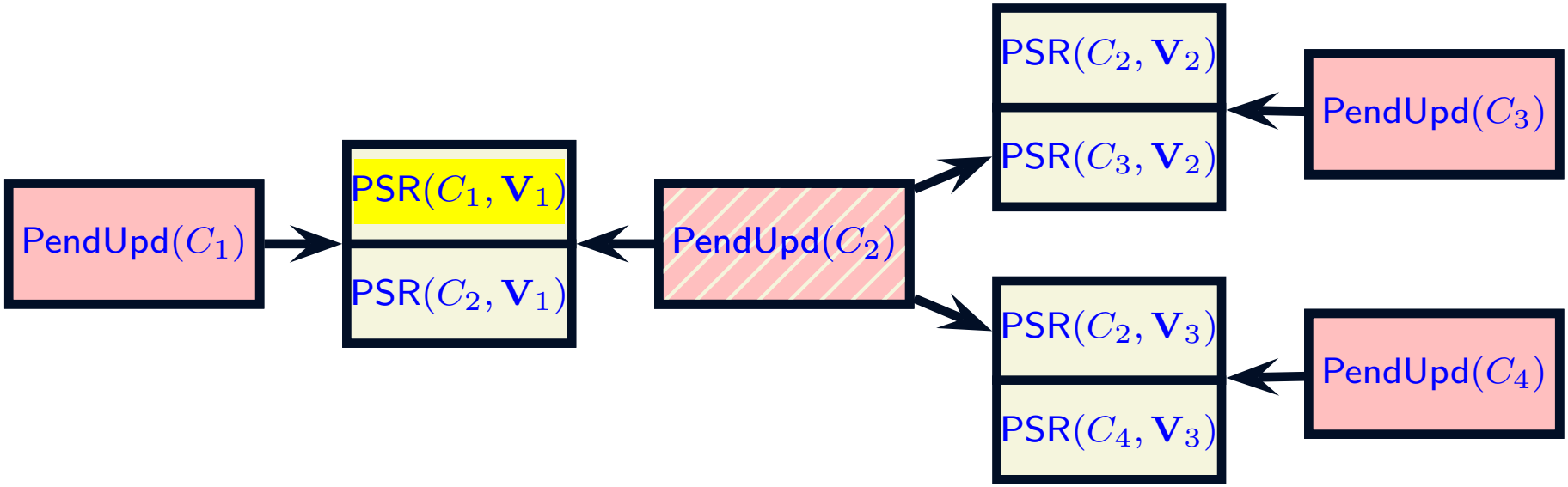
- All port-status registers are initially null.
- An update to a component schema places the corresponding projection into the port status registers of its neighbors.
- The neighbor then identifies a suitable *lifting* of the view state in the port-status register to its schema, and resets that port-status register to null.
- The process repeats, and is nondeterministic.

Operation of Cooperative Update Management



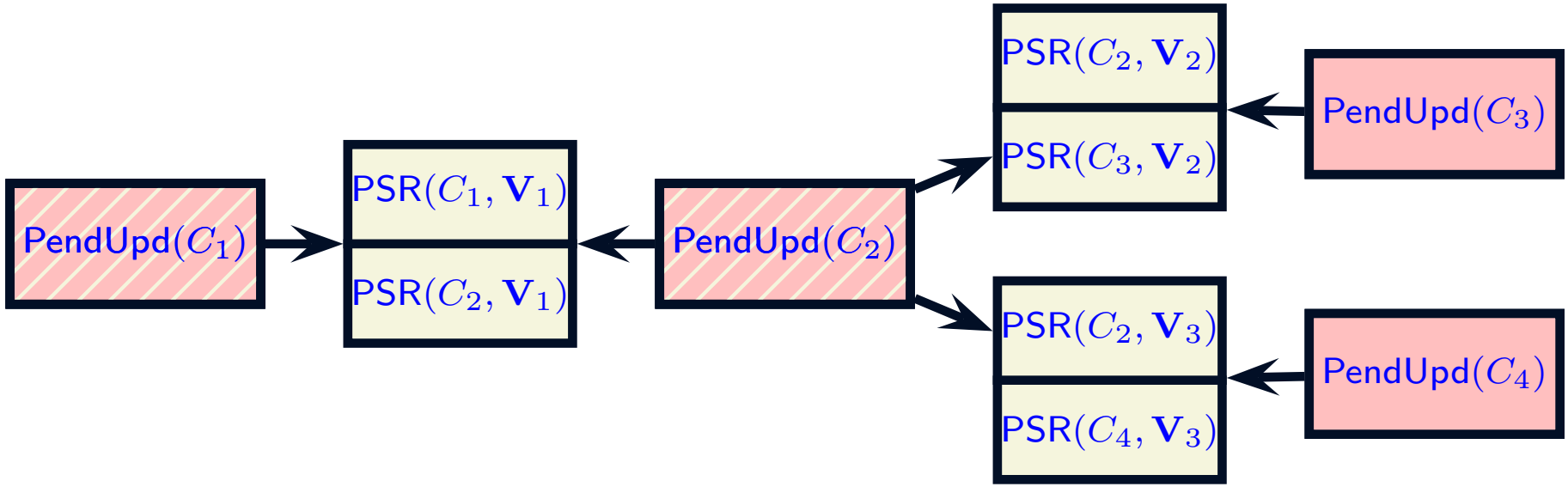
- All port-status registers are initially null.
- An update to a component schema places the corresponding projection into the port status registers of its neighbors.
- The neighbor then identifies a suitable *lifting* of the view state in the port-status register to its schema, and resets that port-status register to null.
- The process repeats, and is nondeterministic.

Operation of Cooperative Update Management



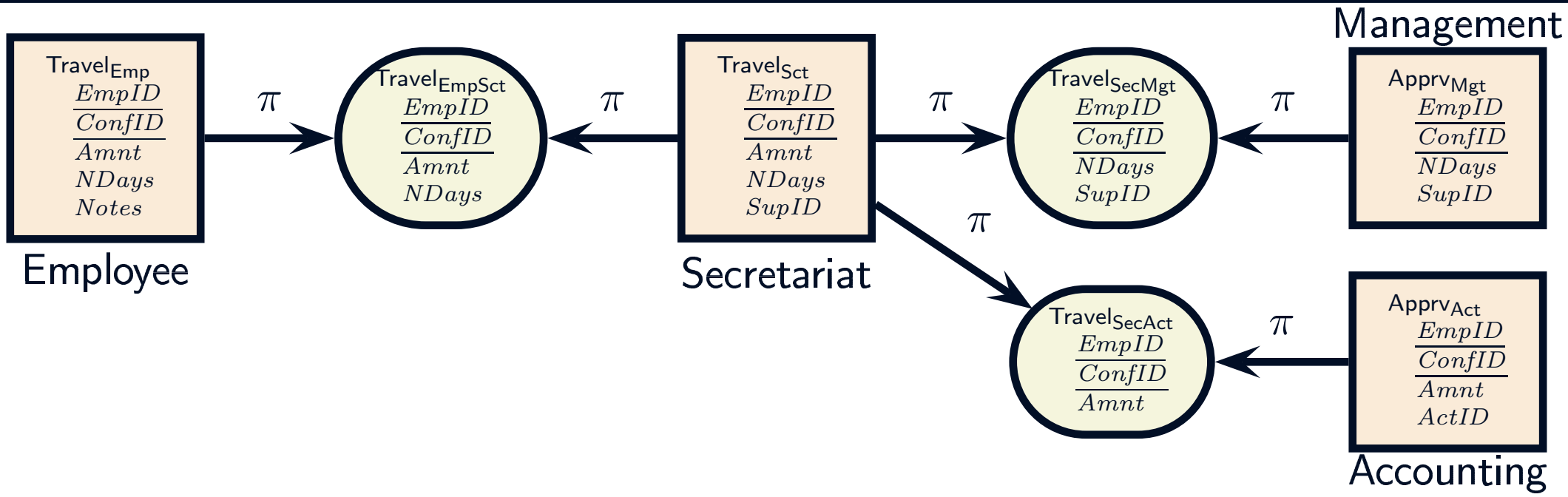
- All port-status registers are initially null.
- An update to a component schema places the corresponding projection into the port status registers of its neighbors.
- The neighbor then identifies a suitable *lifting* of the view state in the port-status register to its schema, and resets that port-status register to null.
- The process repeats, and is nondeterministic.

Operation of Cooperative Update Management

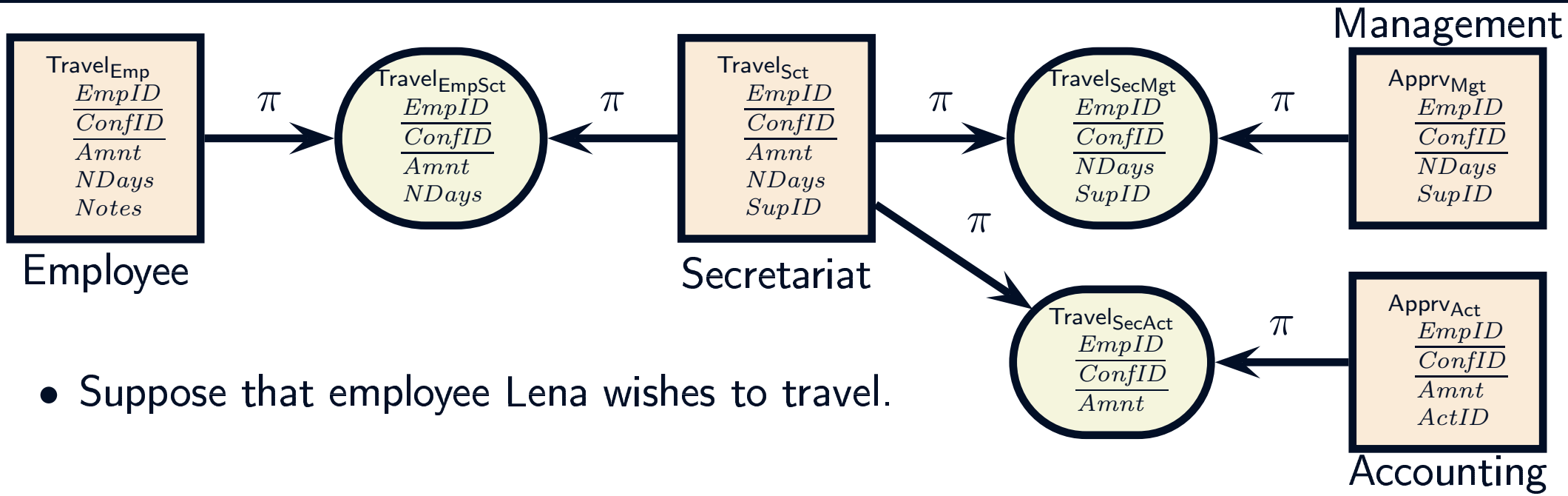


- All port-status registers are initially null.
- An update to a component schema places the corresponding projection into the port status registers of its neighbors.
- The neighbor then identifies a suitable *lifting* of the view state in the port-status register to its schema, and resets that port-status register to null.
- The process repeats, and is nondeterministic.

Example: Travel Request and Authorization

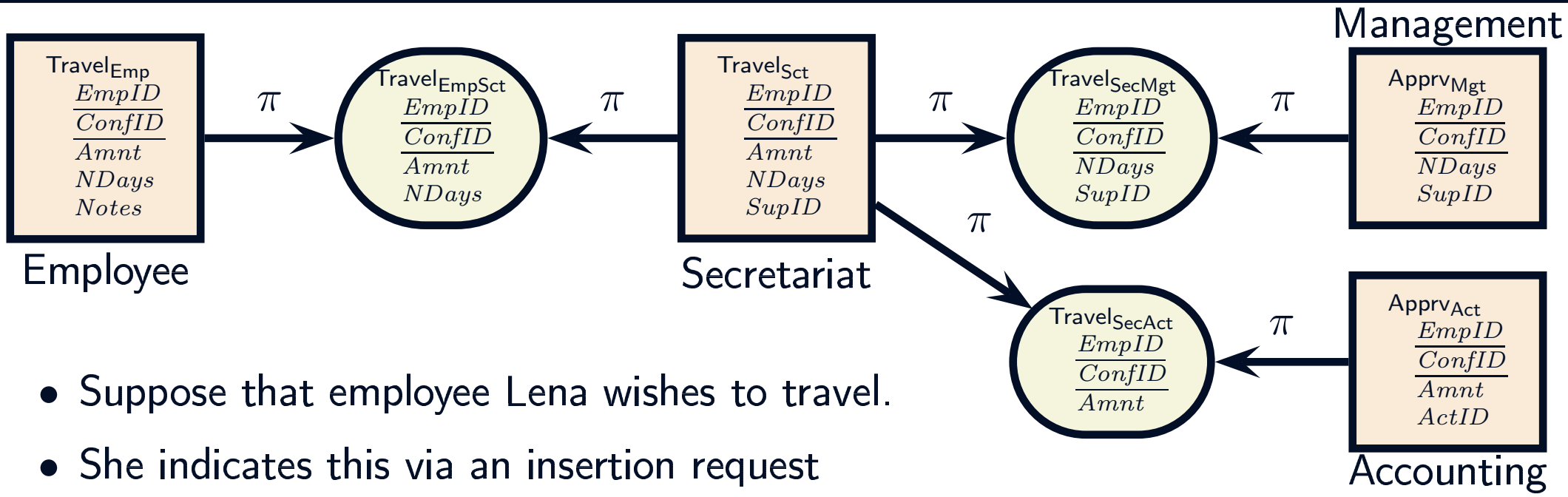


Example: Travel Request and Authorization



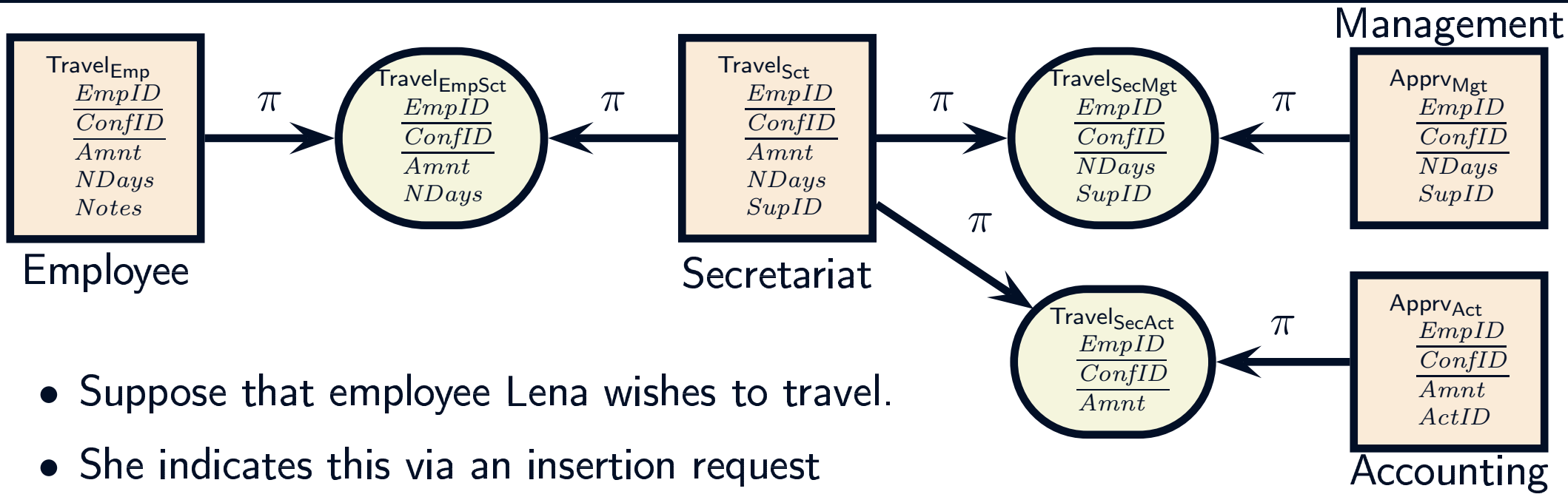
- Suppose that employee Lena wishes to travel.

Example: Travel Request and Authorization



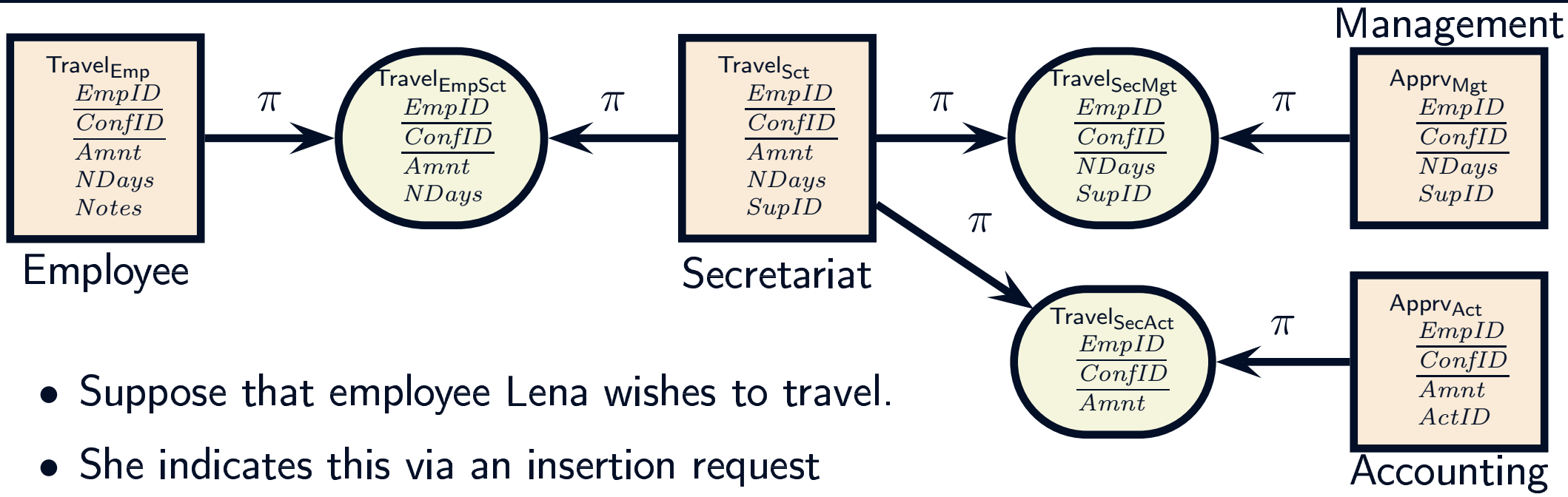
- Suppose that employee Lena wishes to travel.
- She indicates this via an insertion request into the schema of component Employee.

Example: Travel Request and Authorization



- Suppose that employee Lena wishes to travel.
- She indicates this via an insertion request into the schema of component Employee.
- Such a request is typically in the form of a finite *ranked set* of alternatives.

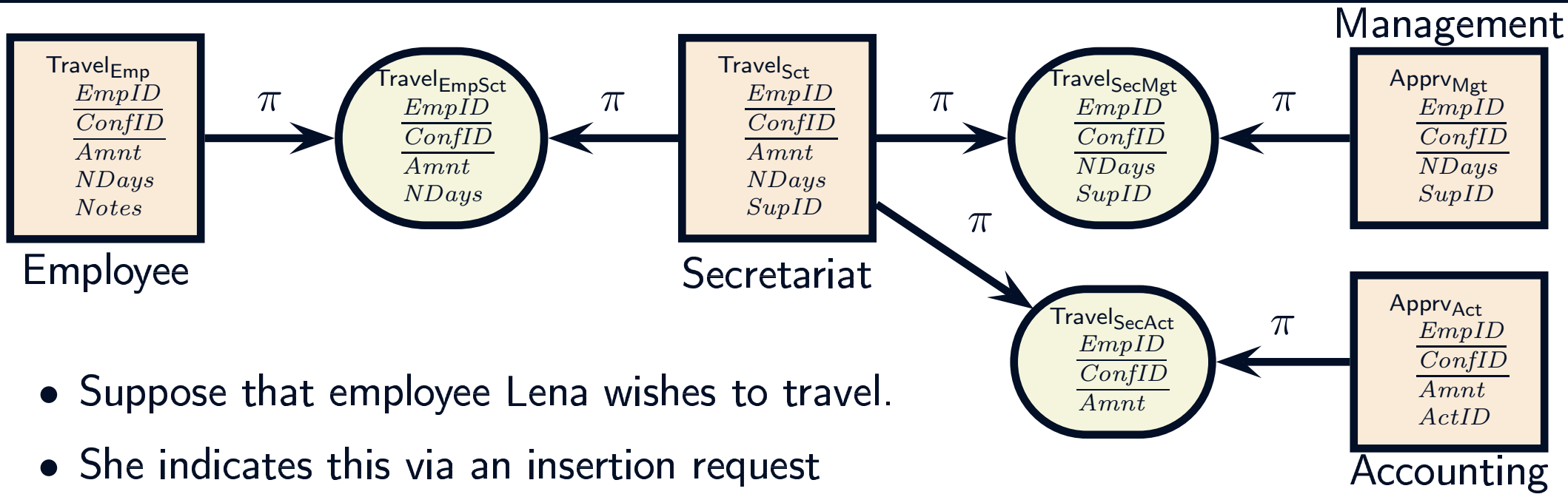
Example: Travel Request and Authorization



- Suppose that employee Lena wishes to travel.
- She indicates this via an insertion request into the schema of component Employee.
- Such a request is typically in the form of a finite *ranked set* of alternatives.

$$\{\mathsf{Travel}_{\mathsf{Emp}}[\mathsf{Lena}, \mathsf{ADBIS}, e_A, d_A, \mathfrak{n}] \mid €800 \leq e_A \leq €2000,\ 5 \leq d_A \leq 10\} \cup$$
$$\{\mathsf{Travel}_{\mathsf{Emp}}[\mathsf{Lena}, \mathsf{DEXA}, e_D, d_D, \mathfrak{n}] \mid €1000 \leq e_D \leq €2000,\ 3 \leq d_D \leq 10\}$$

Example: Travel Request and Authorization

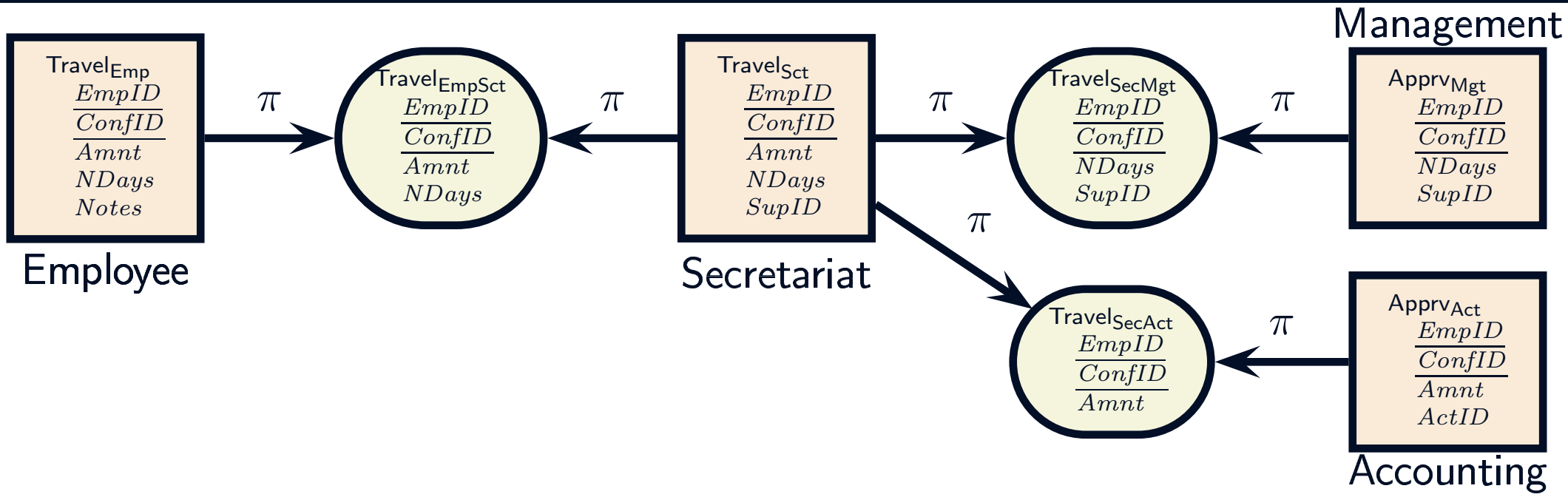


- Suppose that employee Lena wishes to travel.
- She indicates this via an insertion request into the schema of component Employee.
- Such a request is typically in the form of a finite *ranked set* of alternatives.

$$\{\mathsf{Travel}_{\mathsf{Emp}}[\mathsf{Lena}, \mathsf{ADBIS}, e_A, d_A, \mathfrak{n}] \mid €800 \leq e_A \leq €2000,\ 5 \leq d_A \leq 10\} \cup$$
$$\{\mathsf{Travel}_{\mathsf{Emp}}[\mathsf{Lena}, \mathsf{DEXA}, e_D, d_D, \mathfrak{n}] \mid €1000 \leq e_D \leq €2000,\ 3 \leq d_D \leq 10\}$$

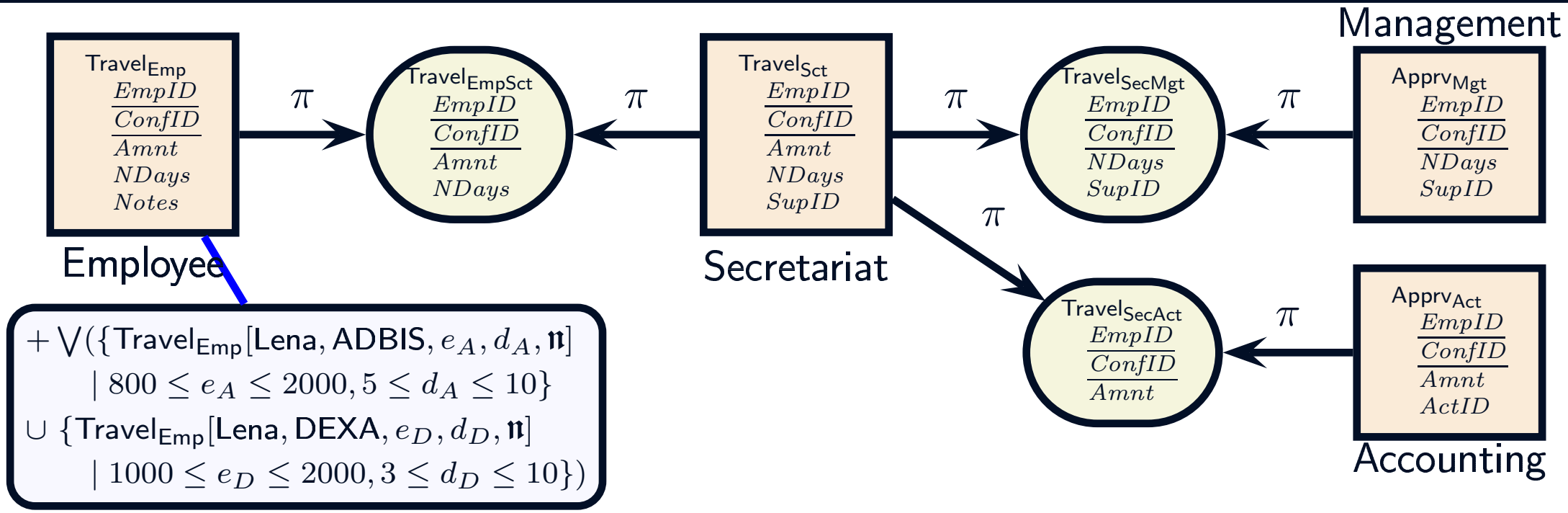
  - ADBIS is always preferred to DEXA.
  - For a given conference, more money and days are always preferred to fewer.

Example: Evolution of Travel Request and Authorization



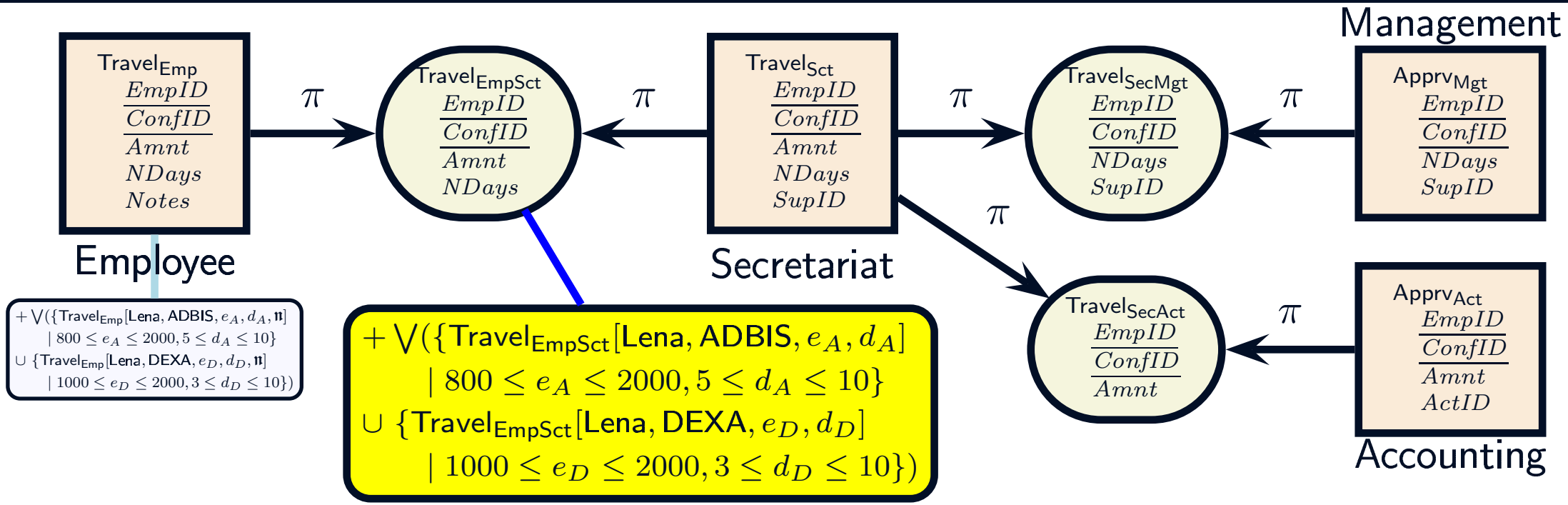
- The evolution of a specific update request will now be illustrated.

Example: Evolution of Travel Request and Authorization



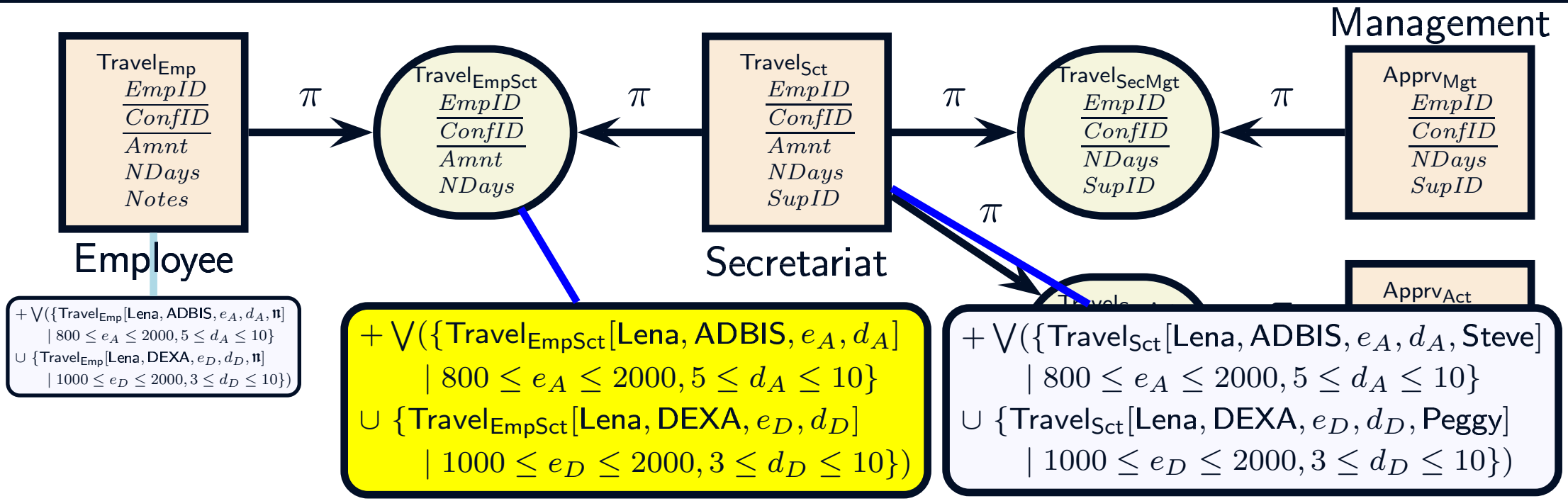
- First, the desired ranked update is entered into the pending-update register for Employee. Notation:
  - $+$ = Insert.
  - $\bigvee$ = Choose one of the alternatives.

Example: Evolution of Travel Request and Authorization



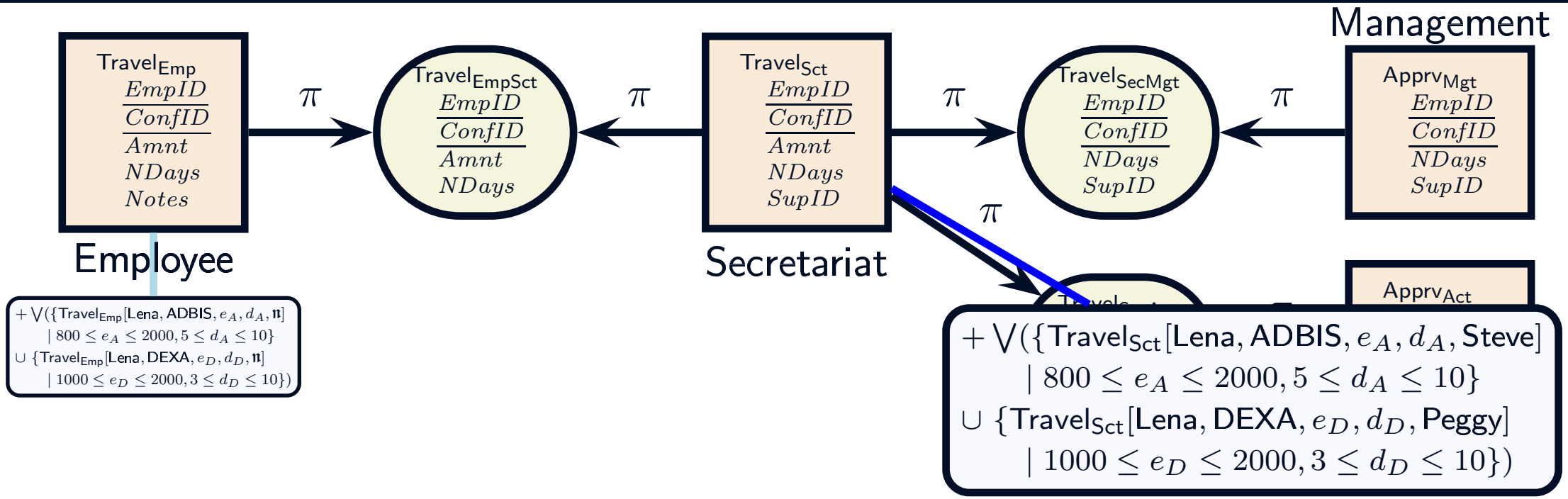
- This update is then projected to the port-status register which connects Employee to Secretariat.

Example: Evolution of Travel Request and Authorization



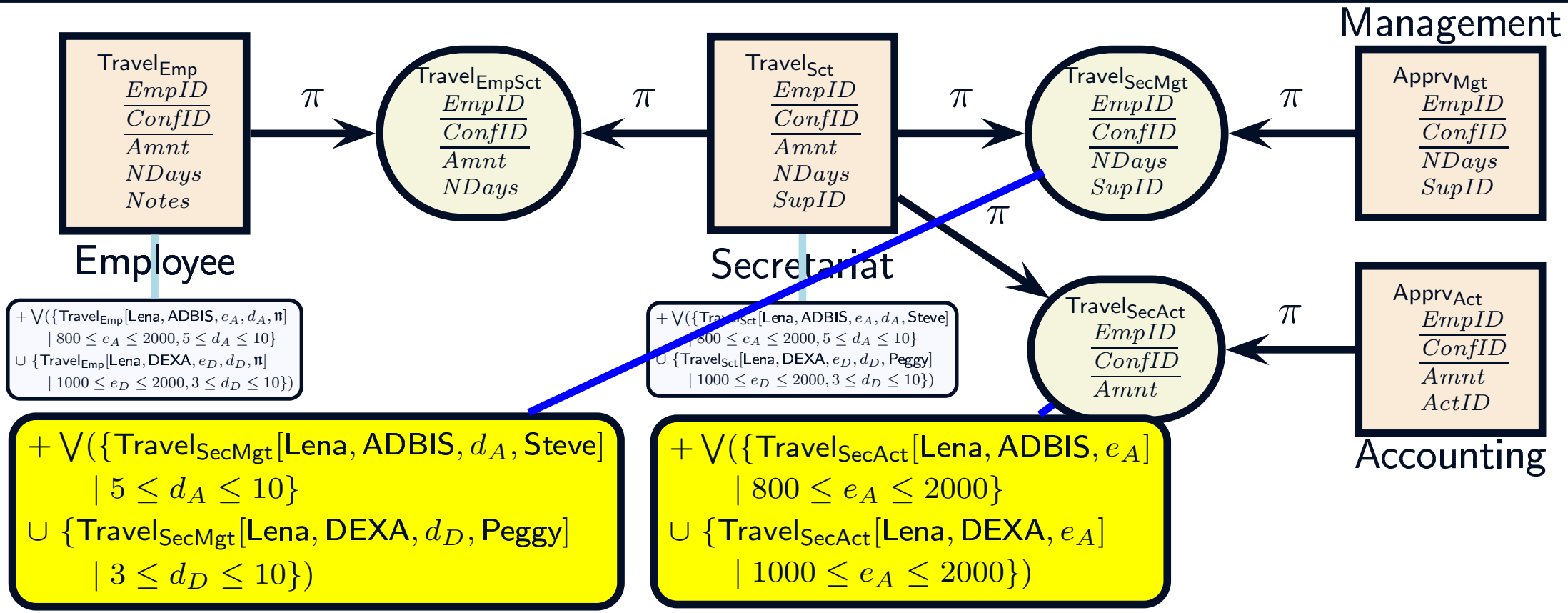
- The user of the Secretariat component then lifts this update to one on that component. It is placed in the pending-update register for that component.
  - Note that decisions must be made.
  - One of many possible liftings must be selected.

Example: Evolution of Travel Request and Authorization



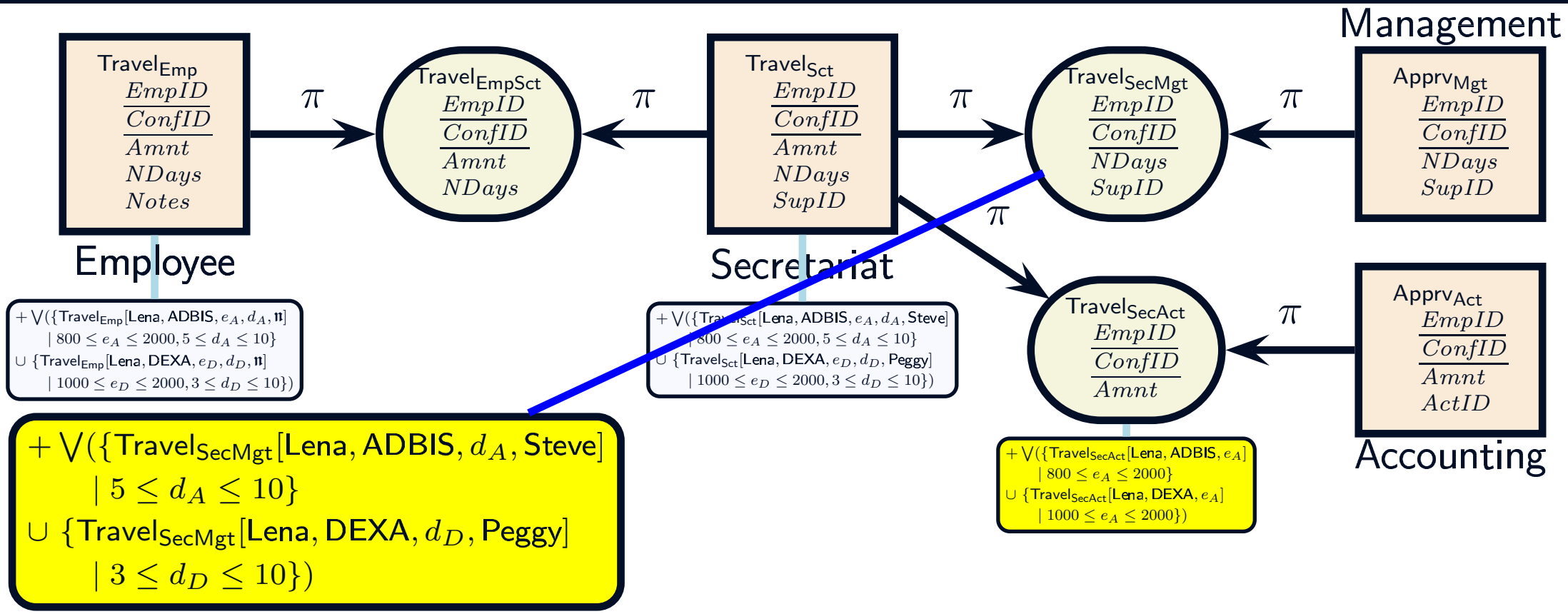
- The port-status register is then cleared, since this update has been processed.

Example: Evolution of Travel Request and Authorization



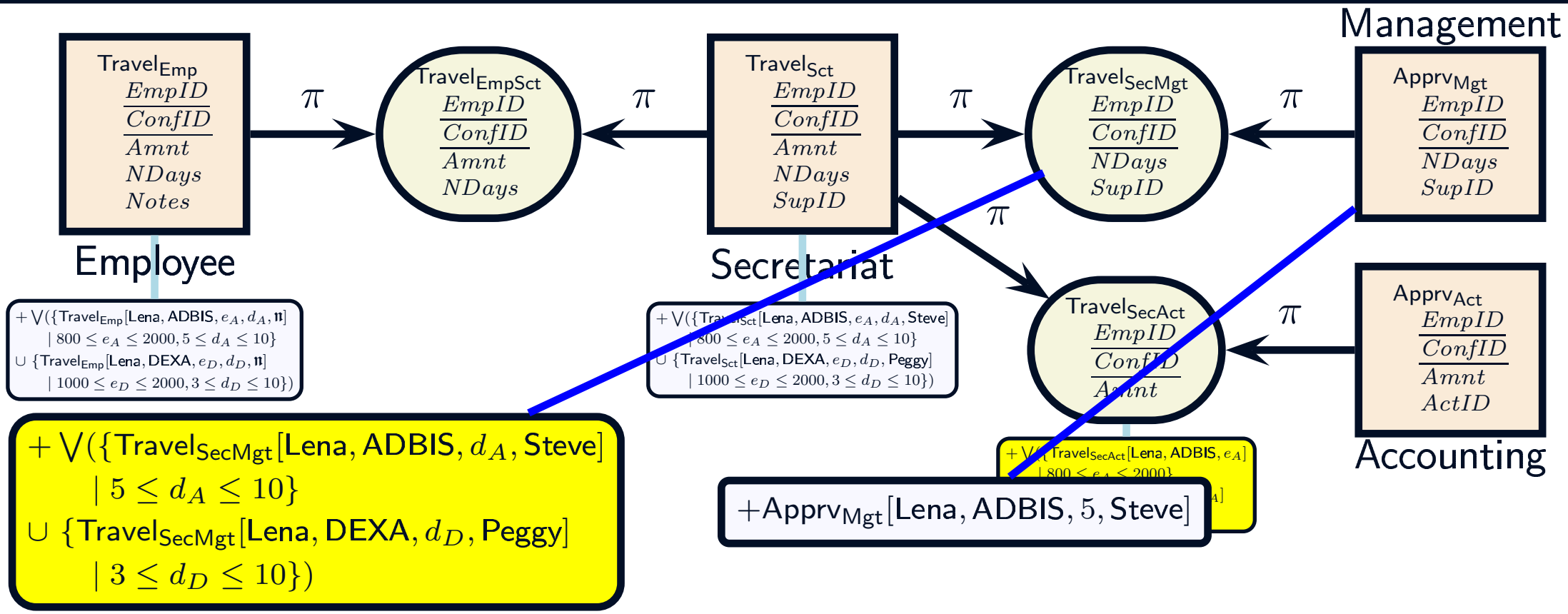
- This lifted update is then projected into the appropriate port-status registers which connect Secretariat to Management and Accounting.
- It is not projected back onto the port-status register which is connected to Employee, because the new value would be the same as the old one.

Example: Evolution of Travel Request and Authorization



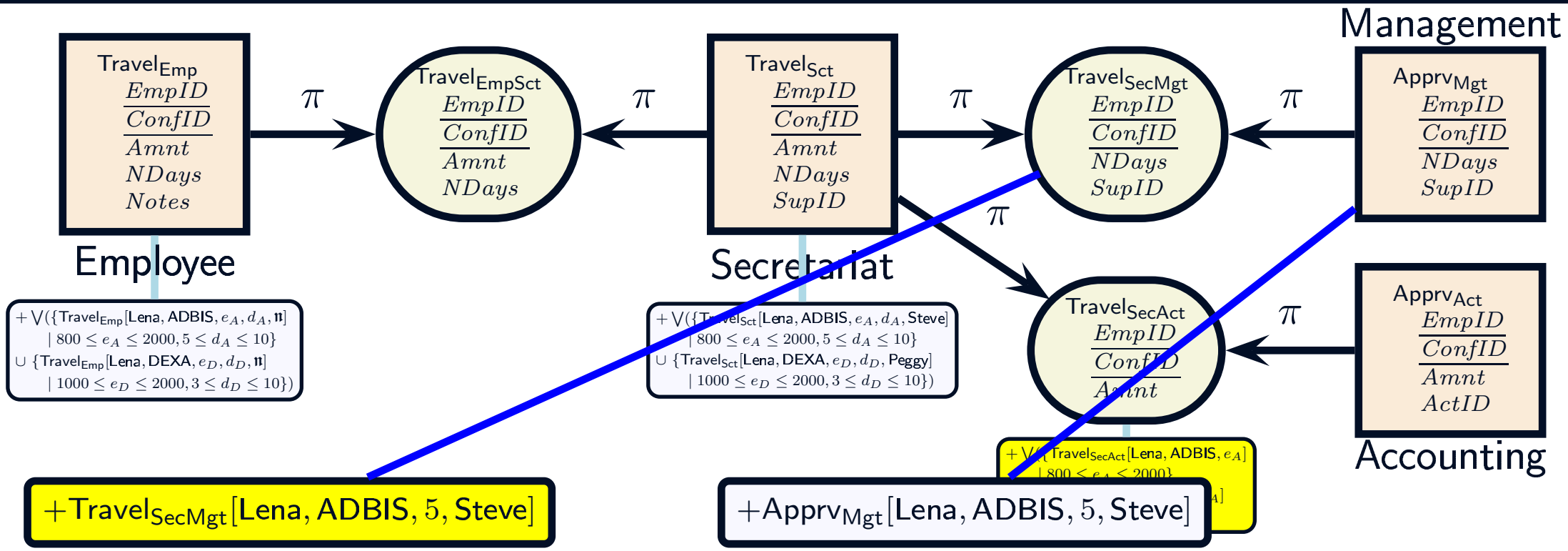
- First consider lifting the projected update to the Management component.
  - Again, there are decisions to be made.

Example: Evolution of Travel Request and Authorization



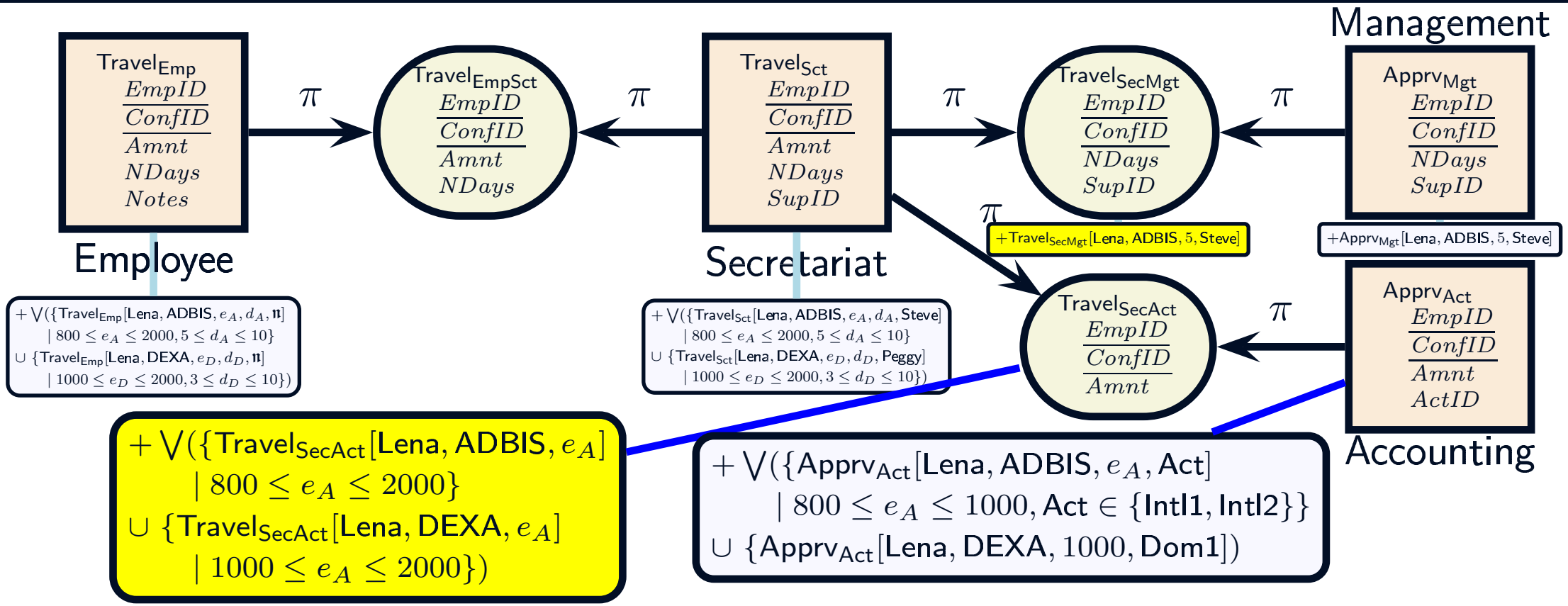
- Manager Steve processes the request, and decides to allow Lena to attend ADBIS for five days.

Example: Evolution of Travel Request and Authorization



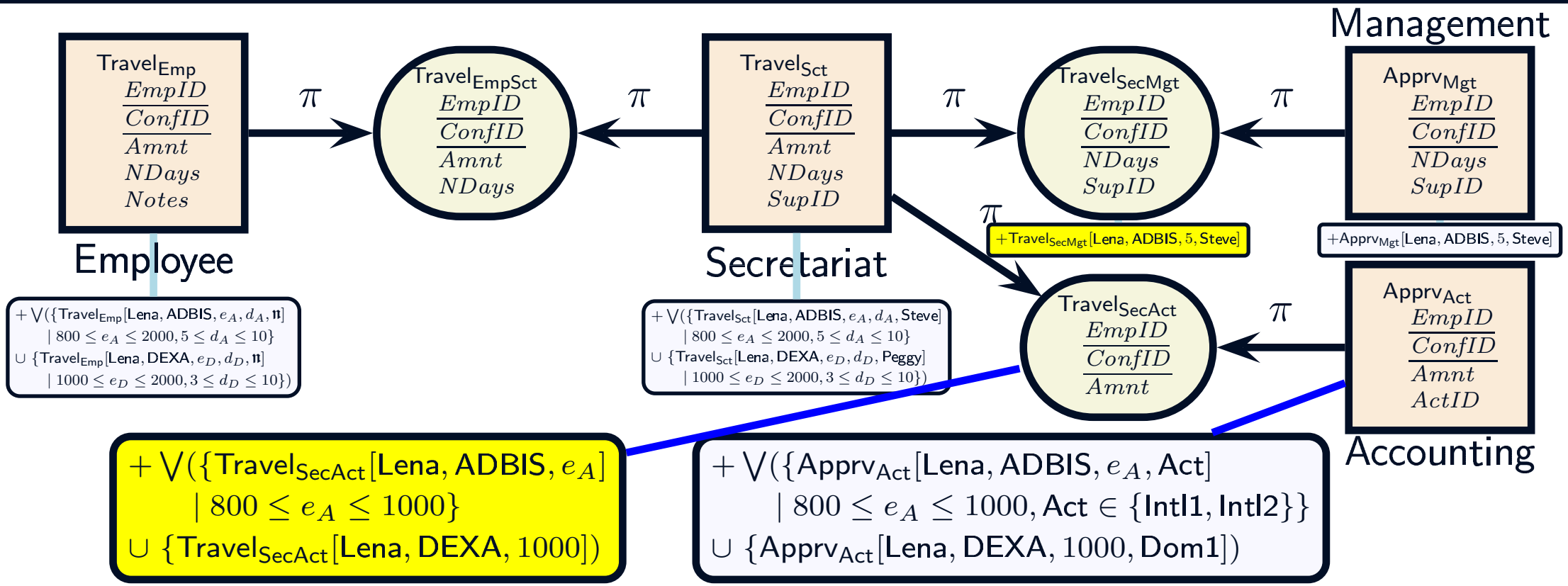
- The value in the port-status register for the Management component is removed, but a new value for the port-status register for Secretariat is inserted.

Example: Evolution of Travel Request and Authorization



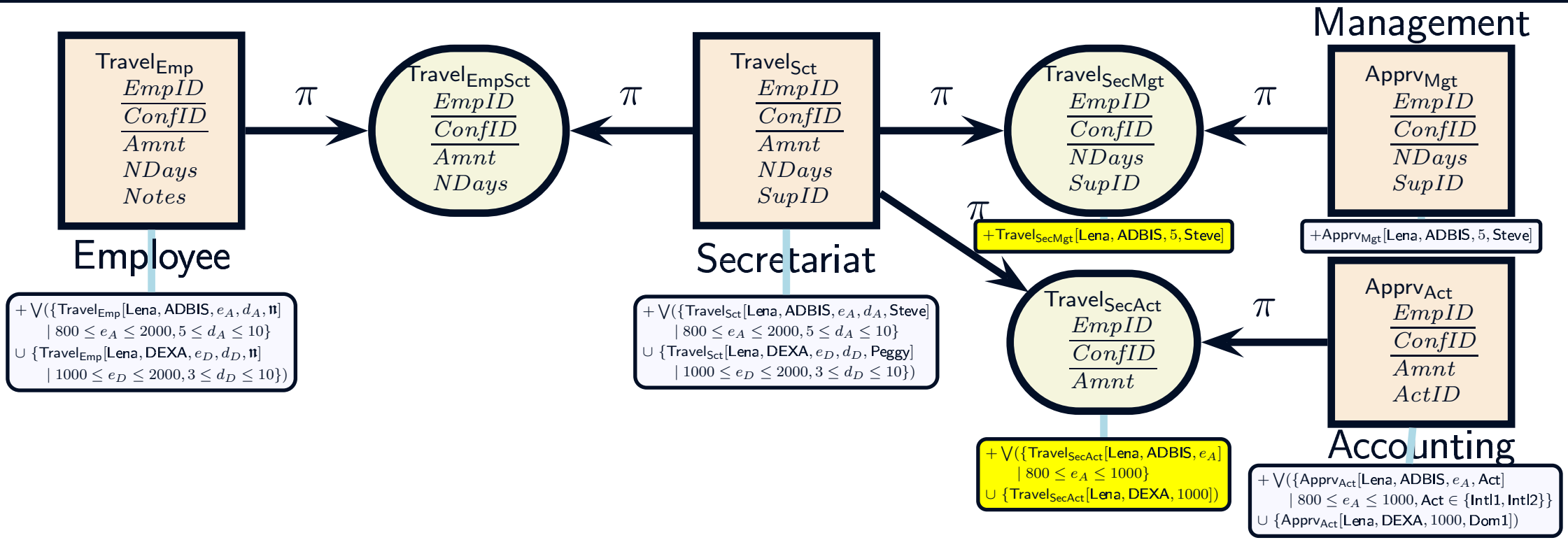
- Now consider lifting the projected update to the Management component.
  - The accounting manager decides to award €1000 for the requested travel.
  - The appropriate accounts are also identified.

Example: Evolution of Travel Request and Authorization



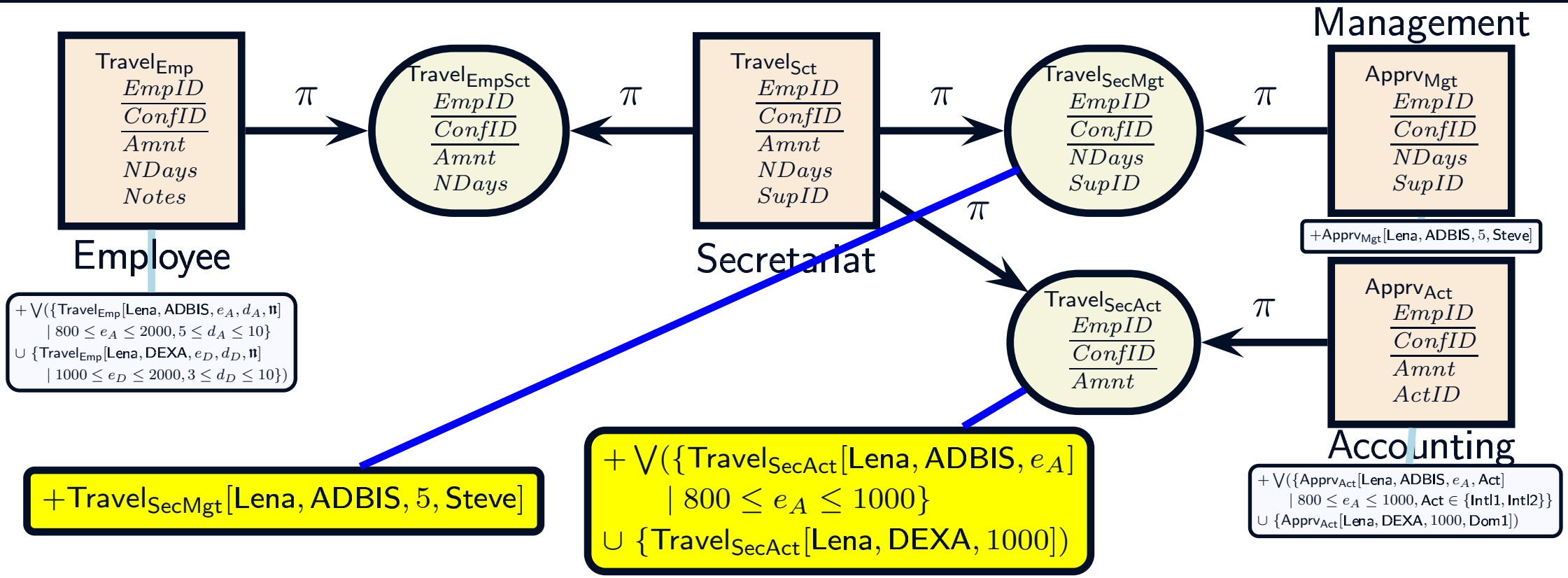
- The value in the port-status register for the Accounting component is cleared, but a new value for the port-status register for Secretariat is inserted.

Example: Evolution of Travel Request and Authorization



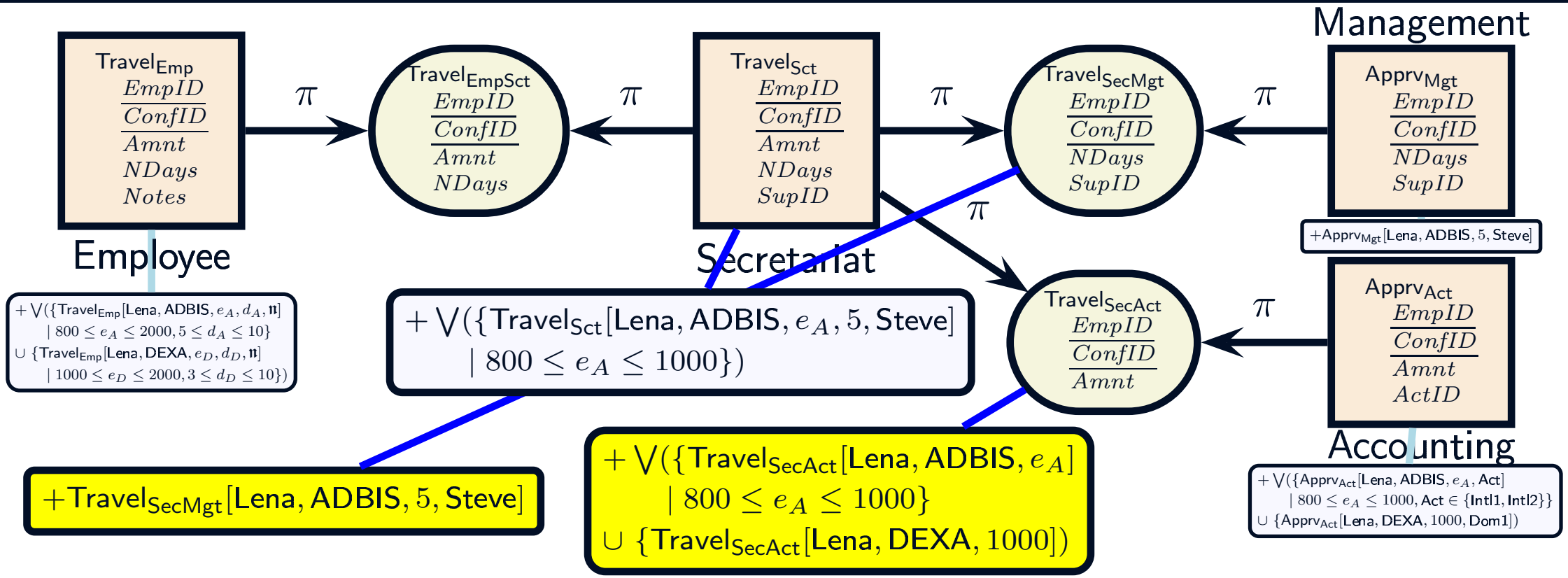
- Now the update negotiation propagates back right to left.

Example: Evolution of Travel Request and Authorization



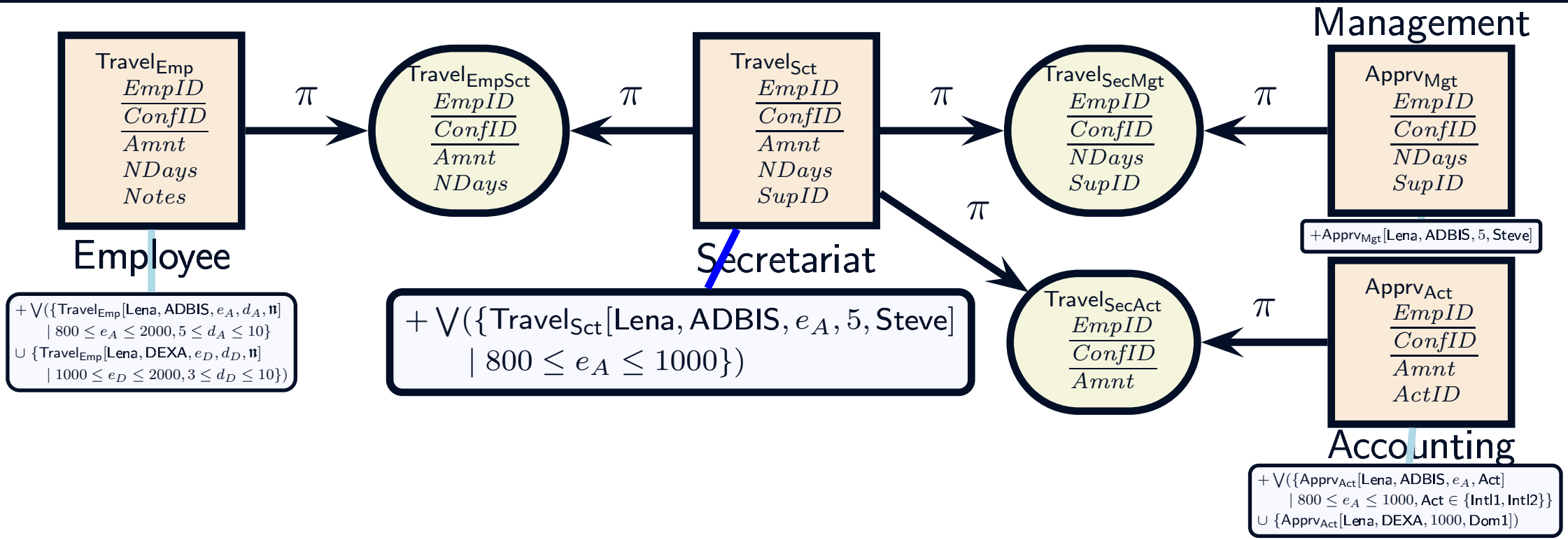
- The two values in the port-status registers must be lifted to the Secretariat component simultaneously.

Example: Evolution of Travel Request and Authorization



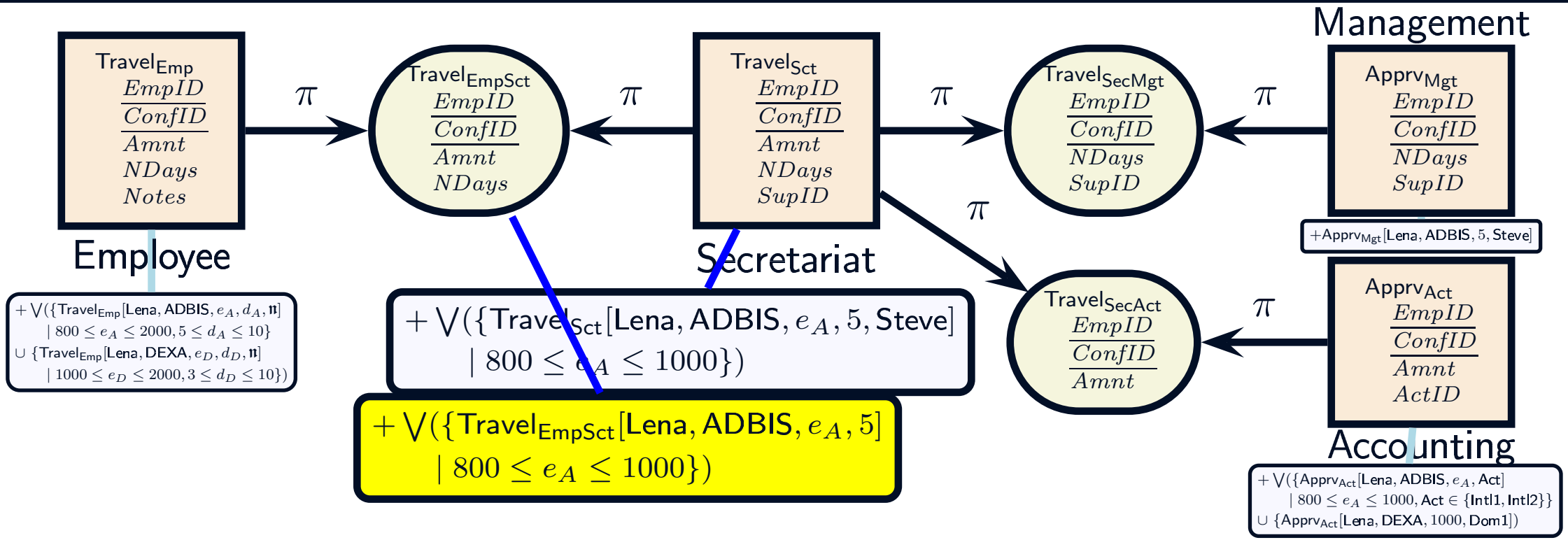
- The maximal lifting is selected.
  - The Secretariat imposes no additional limitations.

Example: Evolution of Travel Request and Authorization



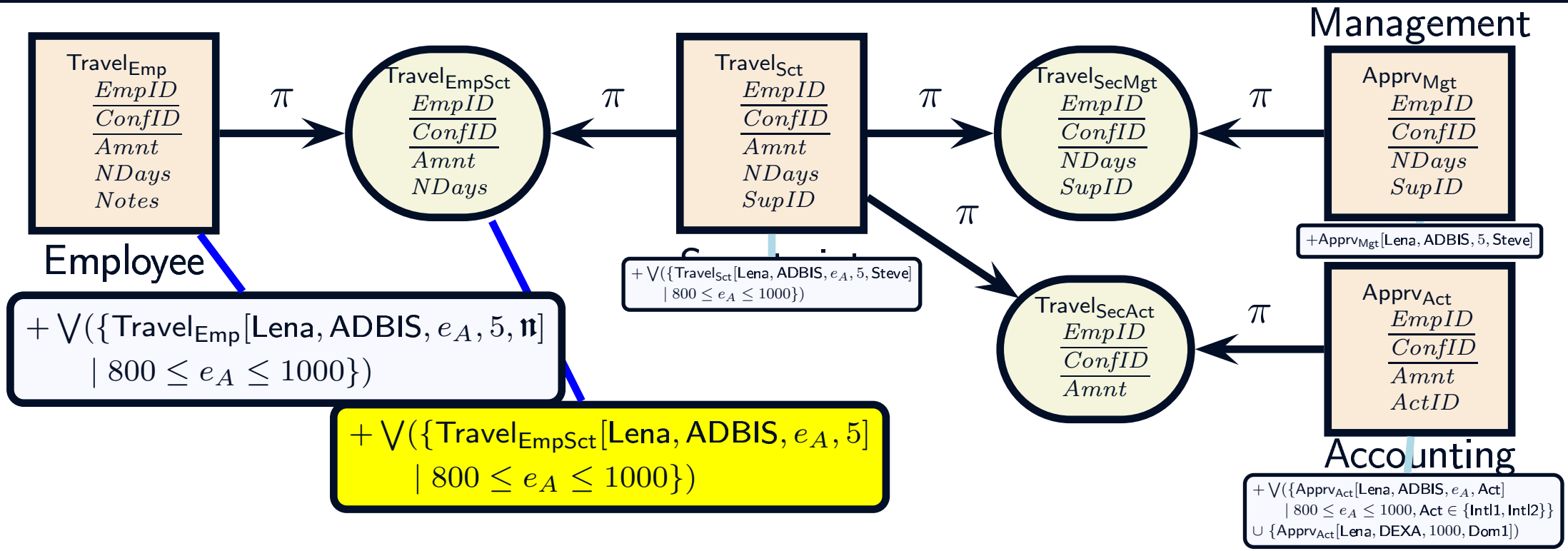
- The two port-status registers are now cleared.

Example: Evolution of Travel Request and Authorization



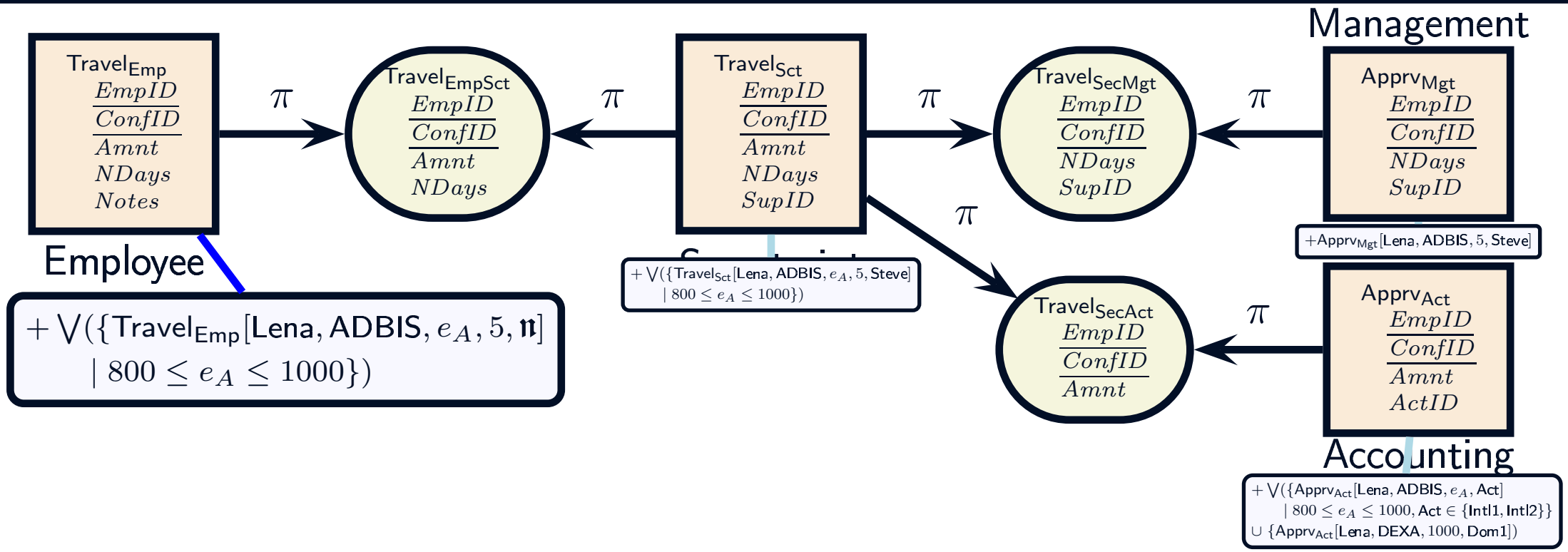
- The update request is then projected to the appropriate port-status register connecting Secretariat to Employee.

Example: Evolution of Travel Request and Authorization



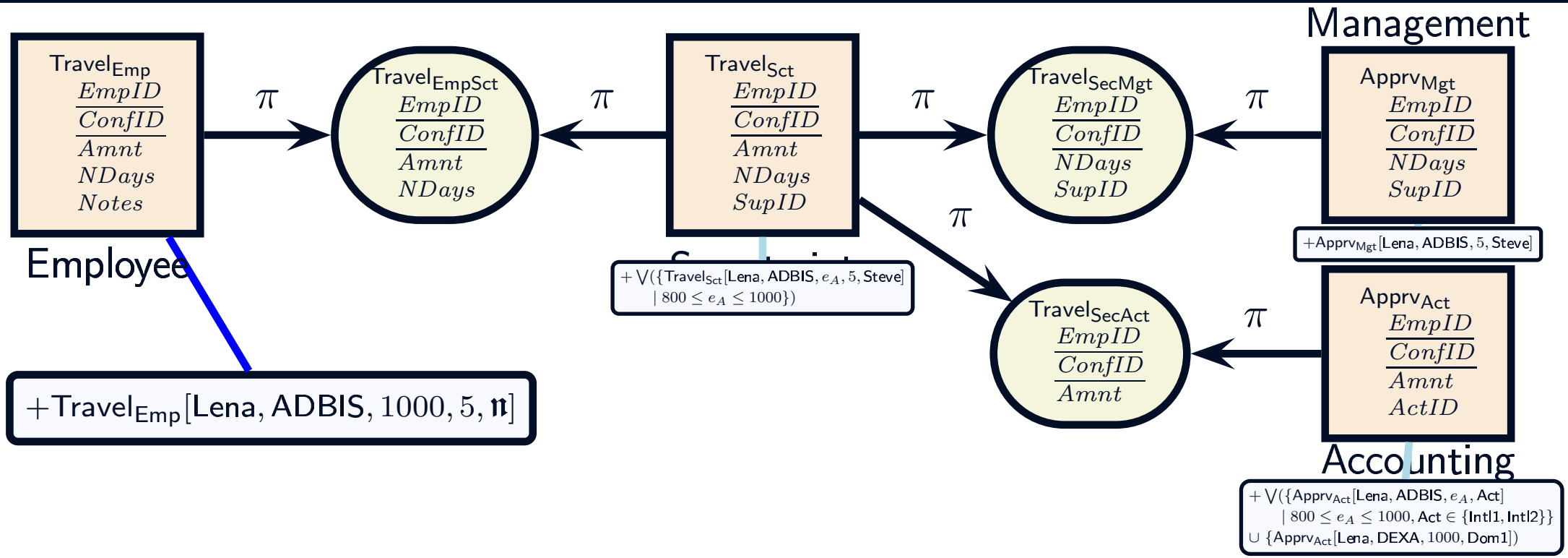
- This update request is then lifted to the Employee component.
  - Again, the maximal lifting is selected.

Example: Evolution of Travel Request and Authorization



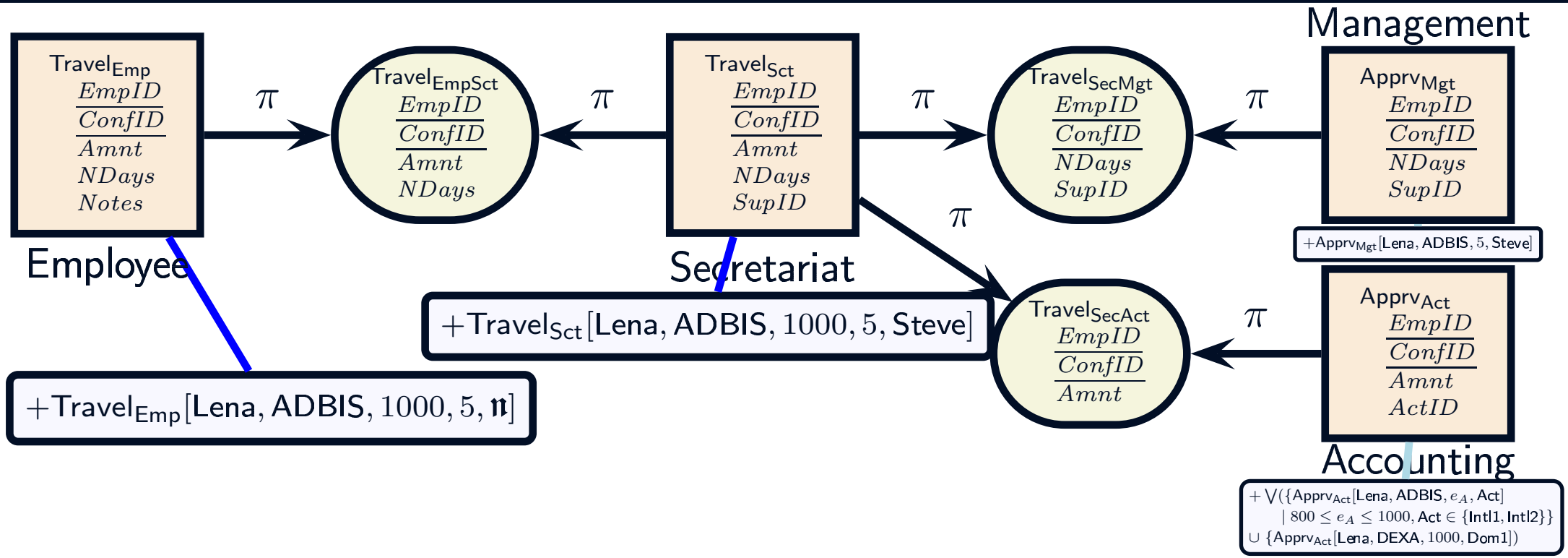
- The port-status register is cleared.
- Note that all port-status registers are now clear.

Example: Evolution of Travel Request and Authorization



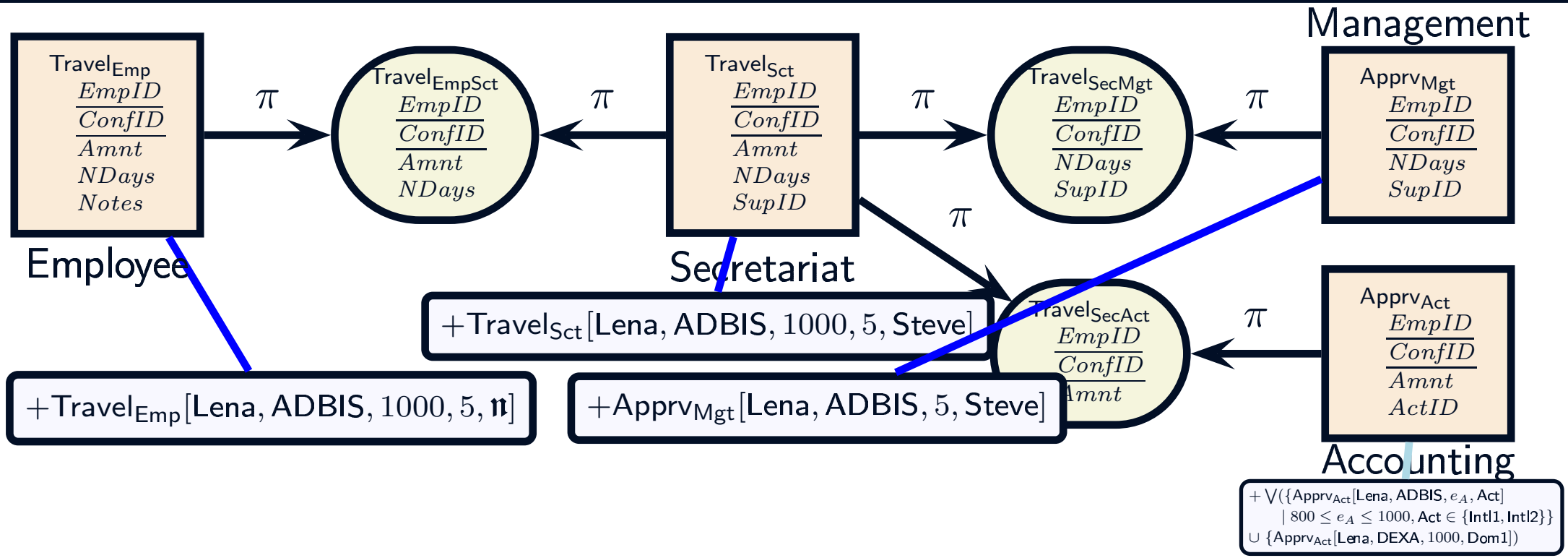
- Finally, Lena selects an update from amongst the possibilities.

Example: Evolution of Travel Request and Authorization



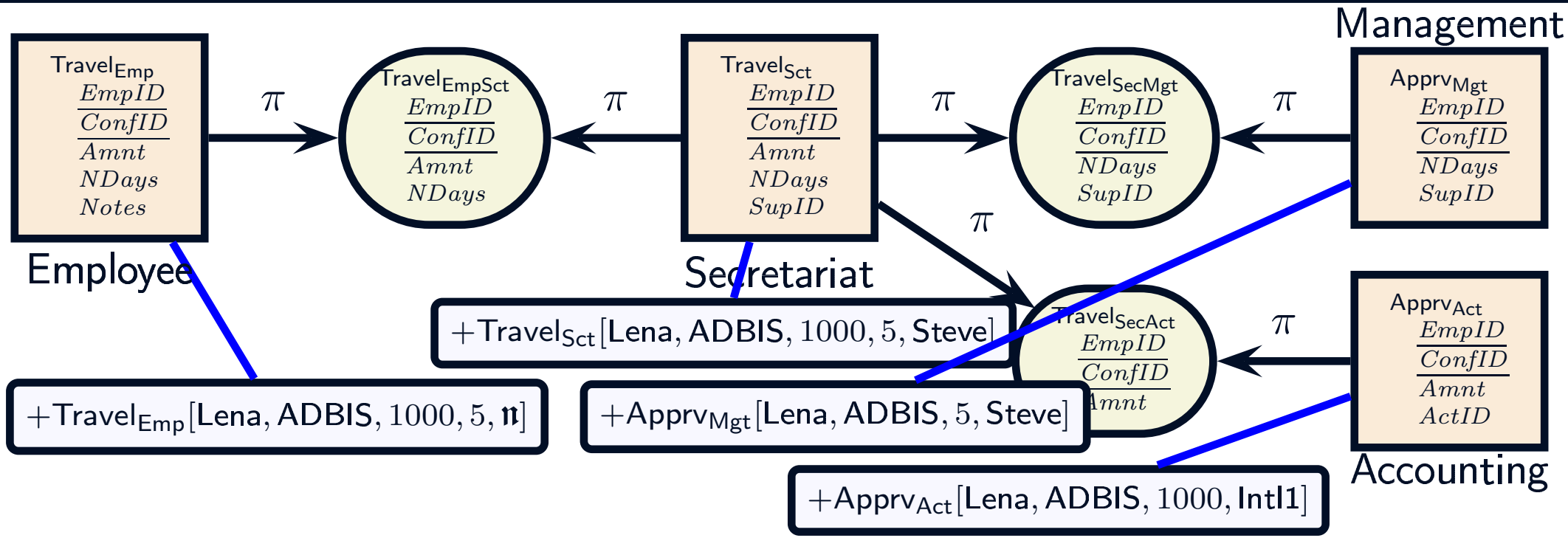
- This update is propagated to the other components for agreement.
- The messages passed through the port-status registers are not shown.

Example: Evolution of Travel Request and Authorization



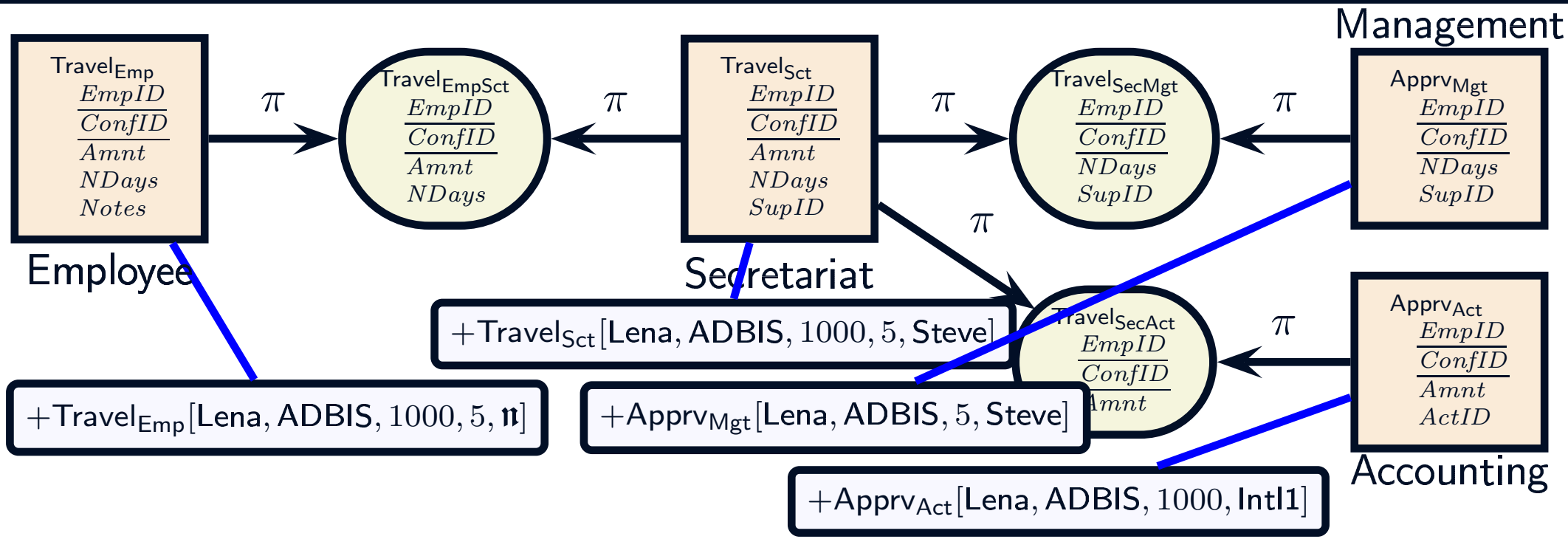
- This update is propagated to the other components for agreement.
- The messages passed through the port-status registers are not shown.

Example: Evolution of Travel Request and Authorization



- This update is propagated to the other components for agreement.
- The messages passed through the port-status registers are not shown.
- Note that a decision of which account to use is made by Accounting, but is not propagated since it is local to that component.

Example: Evolution of Travel Request and Authorization



Commit!

- Finally, these proposed updates may be committed to the database.

Conclusions and Properties of the Solution Technique

- A model for updating database views which is based upon the cooperation of interconnected components has been presented.

Conclusions and Properties of the Solution Technique

- A model for updating database views which is based upon the cooperation of interconnected components has been presented.
- This approach is particularly attractive in situations in which the reflected update requires access privileges beyond those possessed by the user of the view to be updated.

Conclusions and Properties of the Solution Technique

- A model for updating database views which is based upon the cooperation of interconnected components has been presented.
- This approach is particularly attractive in situations in which the reflected update requires access privileges beyond those possessed by the user of the view to be updated.
- The *formal* model is a first, proof-of-concept design, and has the following limitations:

Conclusions and Properties of the Solution Technique

- A model for updating database views which is based upon the cooperation of interconnected components has been presented.
- This approach is particularly attractive in situations in which the reflected update requires access privileges beyond those possessed by the user of the view to be updated.
- The *formal* model is a first, proof-of-concept design, and has the following limitations:
  - It is *opportunistic*: Individual users cannot control the flow of cooperation.

Conclusions and Properties of the Solution Technique

- A model for updating database views which is based upon the cooperation of interconnected components has been presented.
- This approach is particularly attractive in situations in which the reflected update requires access privileges beyond those possessed by the user of the view to be updated.
- The *formal* model is a first, proof-of-concept design, and has the following limitations:
  - It is *opportunistic*: Individual users cannot control the flow of cooperation.
  - It applies only to insertions and deletions.

Conclusions and Properties of the Solution Technique

- A model for updating database views which is based upon the cooperation of interconnected components has been presented.
- This approach is particularly attractive in situations in which the reflected update requires access privileges beyond those possessed by the user of the view to be updated.
- The *formal* model is a first, proof-of-concept design, and has the following limitations:
  - It is *opportunistic*: Individual users cannot control the flow of cooperation.
  - It applies only to insertions and deletions.
  - Negotiation is *monotonic*, in that update proposals can only be refined; additional changes cannot be added after the process begins.

Conclusions and Properties of the Solution Technique

- A model for updating database views which is based upon the cooperation of interconnected components has been presented.
- This approach is particularly attractive in situations in which the reflected update requires access privileges beyond those possessed by the user of the view to be updated.
- The *formal* model is a first, proof-of-concept design, and has the following limitations:
  - It is *opportunistic*: Individual users cannot control the flow of cooperation.
  - It applies only to insertions and deletions.
  - Negotiation is *monotonic*, in that update proposals can only be refined; additional changes cannot be added after the process begins.
- These limitations have the following positive implication.

Conclusions and Properties of the Solution Technique

- A model for updating database views which is based upon the cooperation of interconnected components has been presented.
- This approach is particularly attractive in situations in which the reflected update requires access privileges beyond those possessed by the user of the view to be updated.
- The *formal* model is a first, proof-of-concept design, and has the following limitations:
  - It is *opportunistic*: Individual users cannot control the flow of cooperation.
  - It applies only to insertions and deletions.
  - Negotiation is *monotonic*, in that update proposals can only be refined; additional changes cannot be added after the process begins.
- These limitations have the following positive implication.

Theorem The negotiation process always terminates. Negotiations which proceed indefinitely are not possible. □

Further Directions

Complex negotiation: The following extensions are particularly crucial.

Further Directions

Complex negotiation: The following extensions are particularly crucial.

Nonmonotonicity: Retract existing proposals and replace them with new ones.

Further Directions

Complex negotiation: The following extensions are particularly crucial.

Nonmonotonicity: Retract existing proposals and replace them with new ones.

User-defined control flow: Enable users to determine the flow of control in the negotiation process (in contrast to a purely opportunistic model).

Further Directions

Complex negotiation: The following extensions are particularly crucial.

- **Nonmonotonicity**: Retract existing proposals and replace them with new ones.
- **User-defined control flow**: Enable users to determine the flow of control in the negotiation process (in contrast to a purely opportunistic model).
- **Intra-component negotiation**: Allow several users to negotiate internally within a component.

Further Directions

Complex negotiation: The following extensions are particularly crucial.

- **Nonmonotonicity**: Retract existing proposals and replace them with new ones.
- **User-defined control flow**: Enable users to determine the flow of control in the negotiation process (in contrast to a purely opportunistic model).
- **Intra-component negotiation**: Allow several users to negotiate internally within a component.

Locking and implementation mechanism:

Further Directions

Complex negotiation: The following extensions are particularly crucial.

Nonmonotonicity: Retract existing proposals and replace them with new ones.

User-defined control flow: Enable users to determine the flow of control in the negotiation process (in contrast to a purely opportunistic model).

Intra-component negotiation: Allow several users to negotiate internally within a component.

Locking and implementation mechanism:

- Multi-user cooperative update requires a suitable locking mechanism.

Further Directions

Complex negotiation: The following extensions are particularly crucial.

Nonmonotonicity: Retract existing proposals and replace them with new ones.

User-defined control flow: Enable users to determine the flow of control in the negotiation process (in contrast to a purely opportunistic model).

Intra-component negotiation: Allow several users to negotiate internally within a component.

Locking and implementation mechanism:

- Multi-user cooperative update requires a suitable locking mechanism.
- Implementation of component-based schemata also requires further study.

Further Directions

Complex negotiation: The following extensions are particularly crucial.

Nonmonotonicity: Retract existing proposals and replace them with new ones.

User-defined control flow: Enable users to determine the flow of control in the negotiation process (in contrast to a purely opportunistic model).

Intra-component negotiation: Allow several users to negotiate internally within a component.

Locking and implementation mechanism:

- Multi-user cooperative update requires a suitable locking mechanism.
- Implementation of component-based schemata also requires further study.

Relationship to workflow:

Further Directions

Complex negotiation: The following extensions are particularly crucial.

Nonmonotonicity: Retract existing proposals and replace them with new ones.

User-defined control flow: Enable users to determine the flow of control in the negotiation process (in contrast to a purely opportunistic model).

Intra-component negotiation: Allow several users to negotiate internally within a component.

Locking and implementation mechanism:

- Multi-user cooperative update requires a suitable locking mechanism.
- Implementation of component-based schemata also requires further study.

Relationship to workflow:

- There is an apparent close connection between the flow of control which cooperative update mandates and the notion of *workflow* for complex processes.

Further Directions

Complex negotiation: The following extensions are particularly crucial.

Nonmonotonicity: Retract existing proposals and replace them with new ones.

User-defined control flow: Enable users to determine the flow of control in the negotiation process (in contrast to a purely opportunistic model).

Intra-component negotiation: Allow several users to negotiate internally within a component.

Locking and implementation mechanism:

- Multi-user cooperative update requires a suitable locking mechanism.
- Implementation of component-based schemata also requires further study.

Relationship to workflow:

- There is an apparent close connection between the flow of control which cooperative update mandates and the notion of *workflow* for complex processes.
- The precise way in which cooperative update defines constraints on the possible workflow patterns for the system warrants further study.