Operational Design for Advanced Persistent Threats

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19/10/2020

Advanced Persistent Threat

- Specific targets and clearly defined goals
- Highly organized and well-resourced attackers
- Long-term campaigns with repeated attempts
- Stealth and evasion tactics

(NIST, 2011)

APT – Solutions

Phase
Reconnaissance & weaponization
Delivery
Initial intrusion
Command & control
Lateral movement
Data exfiltration

(Brewer et al., 2014)

APT – Limits

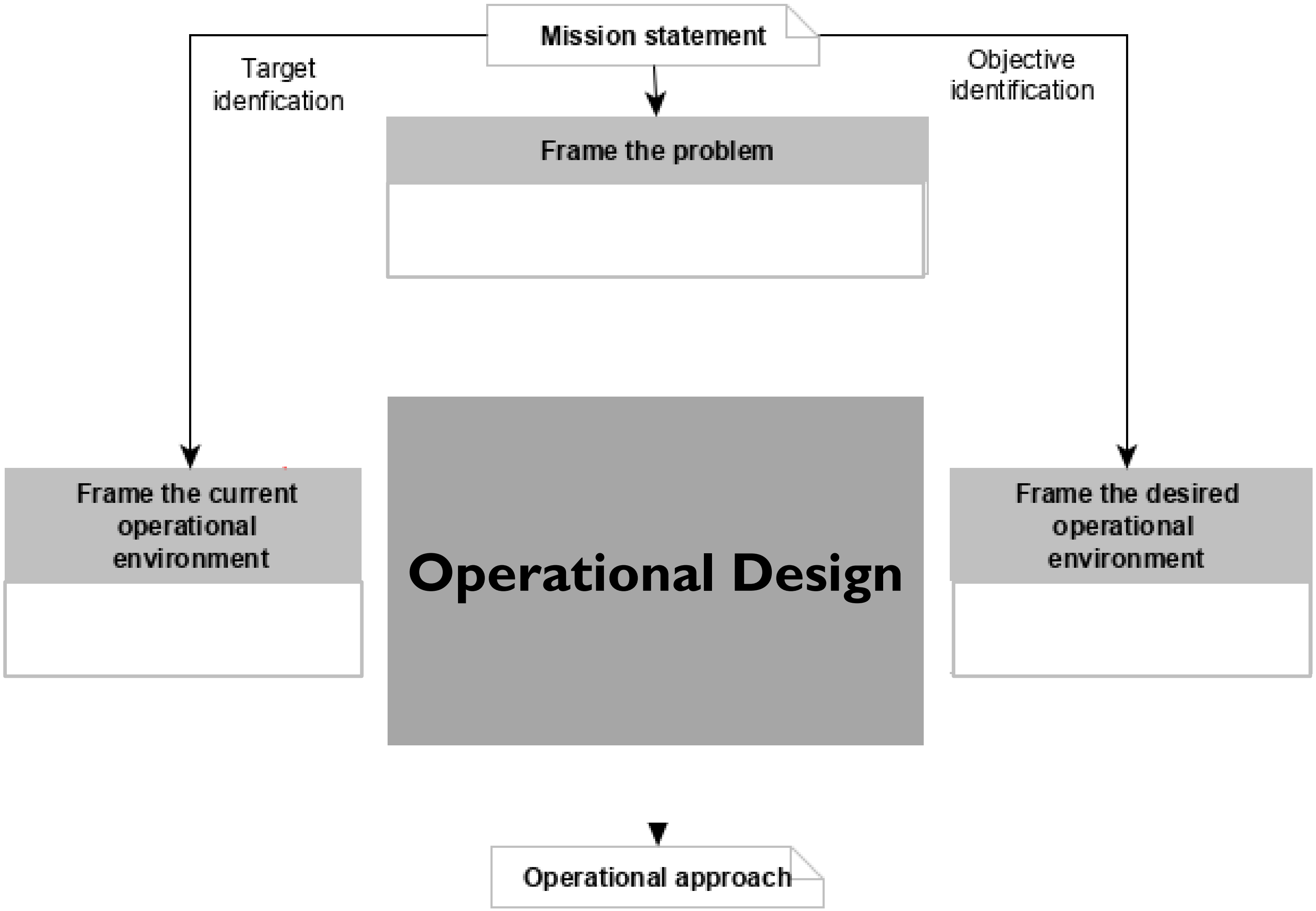
Strategy

Operational Design

Operational Design

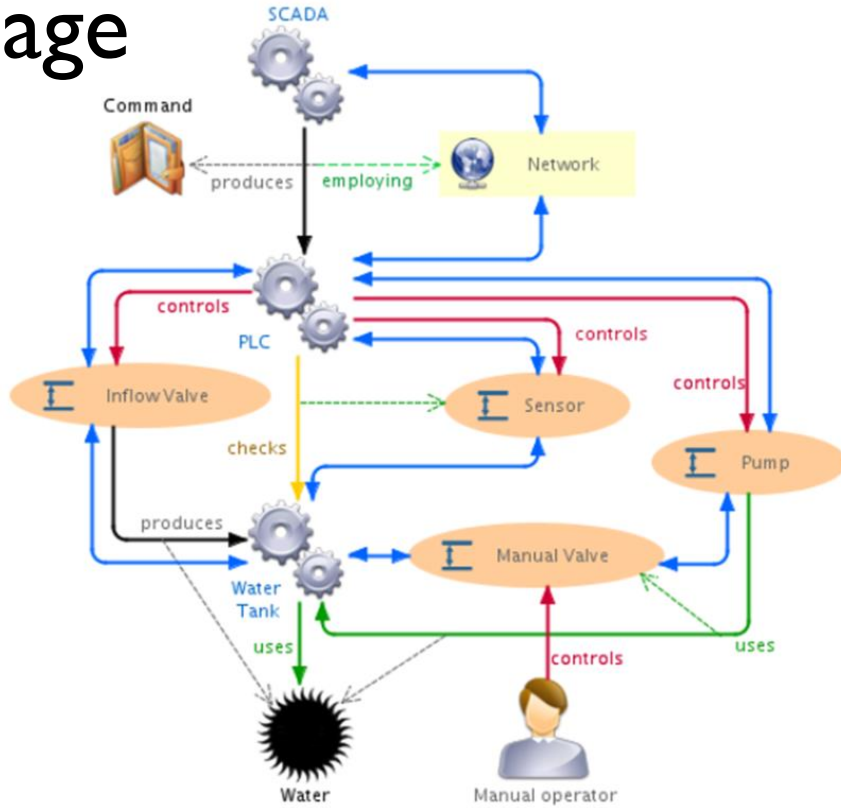
(Graves et al., 2013)

Operational Design



Pimca Framework

- Systems modeling language
  - High-level of abstraction
  - Graphical
  - Geared toward security



(Sun et al., 2020)

Pimca Framework

- Dynamic extension requirement
  - System behavior framing
  - Desired environment framing
  - Problem framing

System Behavior

A **behavioral model** is defined as:

$$M = <\mathbb{V}, \mathbb{A}, \mathbb{S}>$$

- $\mathbb{V}$ is a set of variables

  $val_{\mathbb{V}}$ is the set of possible valuations over $\mathbb{V}$
- $\mathbb{A}$ is a set of guarded-commands
- $\mathbb{S}$ is a set of synchronisation channels

System Behavior

A **guarded-command** is defined as:

$$G_c = < u, s, g, c >$$

- $u : \mathbb{B}$, denotes if G_c is urgent
- $s : \mathbb{S} \cup \{none\}$, is a synchronisation channel (or absence of)
- $g : val_{\mathbb{V}} \rightarrow \mathbb{B}$, is a boolean expression of the model variables
- $c : val_{\mathbb{V}} \rightarrow val_{\mathbb{V}}$, is a sequence of statements

```
GC_name :
    urgent ?
    (channel ( ? | ! )) ?
    [guard] ? /
    (command ;) *
```

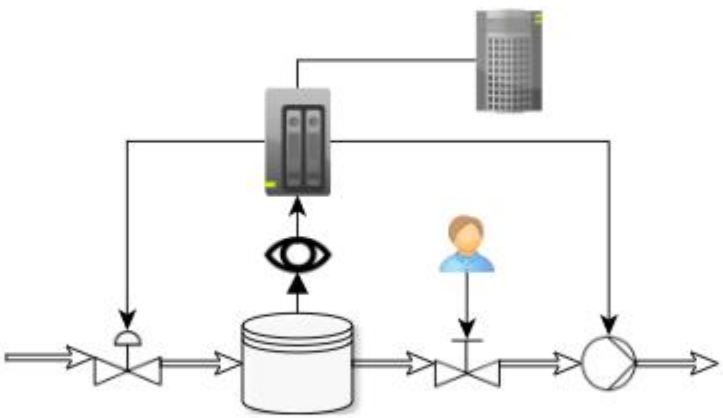
Execution rules :

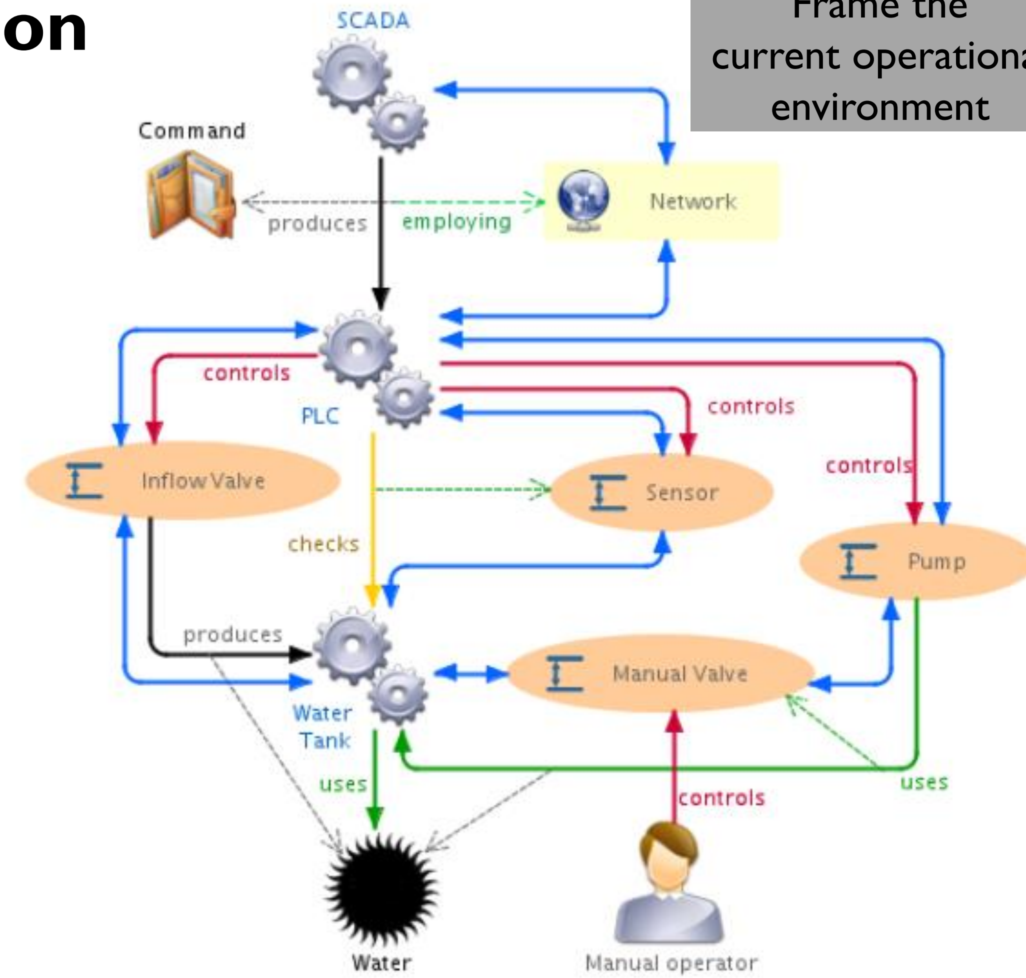
- A guarded-command can only be executed if its guard is *true* on the current valuation.
- Only one guarded-command can be executed at a time.
- If a guarded-command uses a synchronisation channel, it must be executed sequentially in a single step alongside a synced guarded-command in the following order : (emission, reception).
- If any urgent guarded-command can be executed on the current valuation, the next execution step must involve an urgent guarded-command.

Case study

Water pumping station

Frame the current operational environment





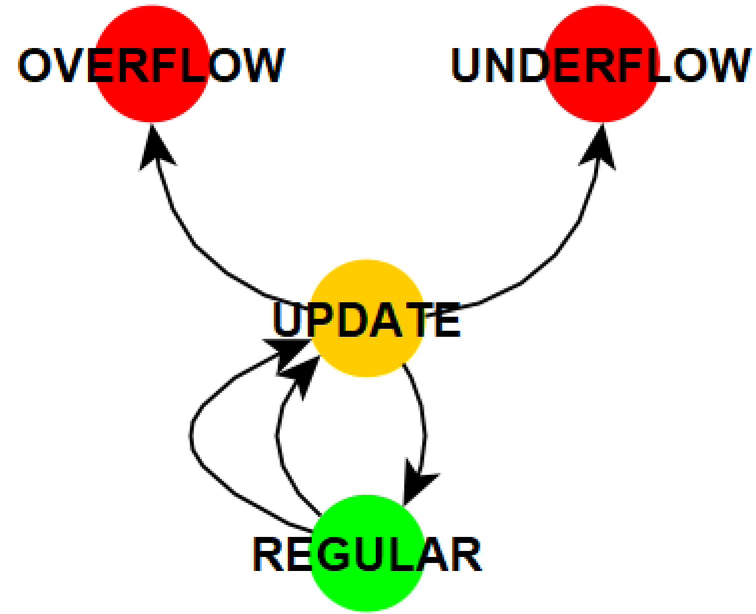
Frame the current operational environment

Water pumping station

Water tank

Role: to update the *waterLevel* variable

- flowIn
- flowOut
- refreshSensor
- overflow
- underflow



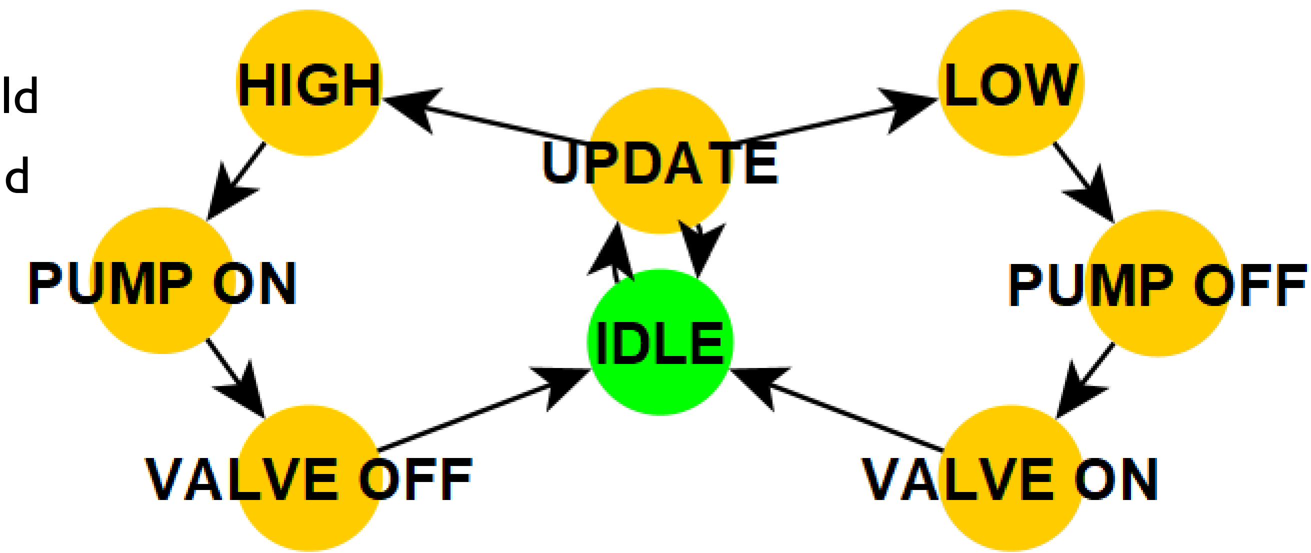
Water pumping station

Frame the current operational environment

PLC

Role : to control the water flow through actuators and sensors

- update
- regular
- highThreshold
- lowThreshold
- valveOn
- valveOff
- pumpOn
- pumpOff



Case study

Water pumping station

Frame the current operational environment

WaterTank	PLC	InflowValve	ManualValve	Pump	Sensor	Operator
flowIn	update	flowOut	flowIn	flowIn	update	input
flowOut	regular	open	flowOut	open	refreshPLC	
refreshSens	highThres	close	open	close		
overflow	lowThres		close			
underflow	valveOn					
	valveOff					
	pumpOn					
	pumpOff					

Case study

Water pumping station

Frame the desired operational environment

Desired environment:

- Overflow the water tank
- Remain undetected

Expressed using LTL:

$$(\Diamond overflow) \land (\Box !\, alert)$$

Case study

Water pumping station

Leverage capabilities:

- force the inflow valve open
- block the pump
- close the manual valve
- disable the sensor
- jam the network

Frame the problem

InflowValve	Pump
forceOpen	block
close*	open*

Sensor	Network
disable	jam
refreshPLC*	send*

Water pumping station

Objectives satisfaction?

Model-checking using OBP2:

Force (open) inflow valve		●			●	●			●		●	●
Close manual valve			●			●		●				●
Block pump				●	●			●			●	
Jam network							●	●	●		●	●
Disable sensor										●		
Sub-objective 1	X	X	X	X	O	O	X	X	X	O	O	O
Sub-objective 2	X	X	X	X	X	X	O	O	O	O	O	O

TABLE 2: Model-checking of the water pumping station (O: success, X: failure)

Operational approach: disabling the sensor is the simplest path to achieving the mission

Conclusion

Modeling the APT strategy planning

- Adapted from Operational Design
- Pimca framework
- Model-checking

Future works

- Methodology refining, user study
- Problem framing formalization

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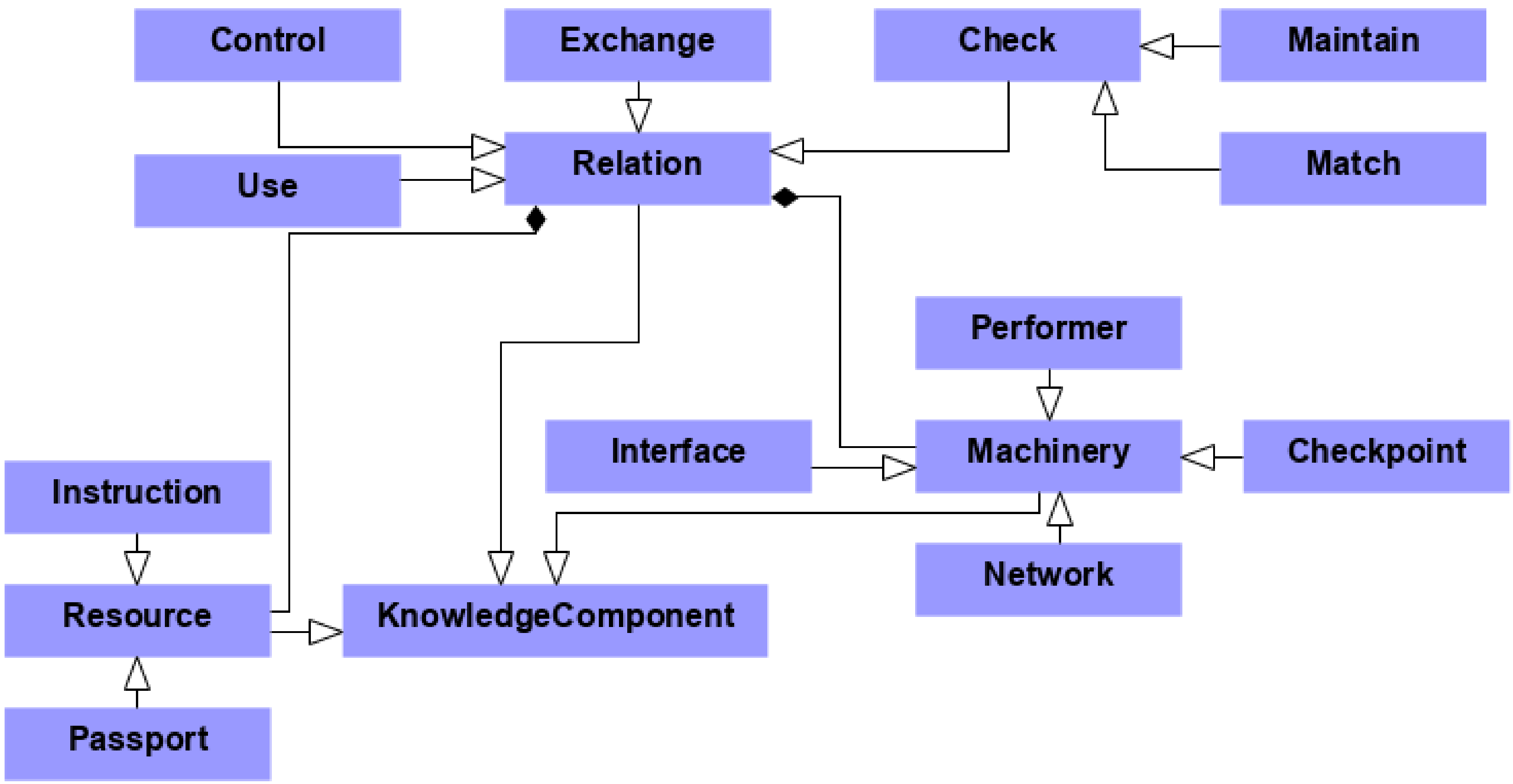
- Class diagram



Execution rules

$$single_u : \frac{\forall (u, \mathbf{none}, g, c) \in \mathbb{A}, \forall \rho_1, \rho_2 \in val_{\mathbb{V}} \quad u \wedge g(\rho_1) \wedge c(\rho_1) = \rho_2}{\langle \underset{\mathbb{A}}{\|}, \rho_1 \rangle \rightarrow \rho_2}$$

$$single : \frac{\forall (u, \mathbf{none}, g, c) \in \mathbb{A}, \forall \rho_1, \rho_2 \in val_{\mathbb{V}} \quad \neg hasUrgent_{\mathbb{A}}(\rho_1) \wedge \neg u \wedge g(\rho_1) \wedge c(\rho_1) = \rho_2}{\langle \underset{\mathbb{A}}{\|}, \rho_1 \rangle \rightarrow \rho_2}$$

$$sync_u : \frac{\forall (u_1, (\mathbf{out}, id), g_1, c_1), (u_2, (\mathbf{in}, id), g_2, c2) \in \mathbb{A}, \forall \rho_1, \rho_2 \in val_{\mathbb{V}} \quad (u_1 \vee u_2) \wedge g_1(\rho_1) \wedge g_2(\rho_1) \wedge c_2(c_1(\rho_1)) = \rho_2}{\langle \underset{\mathbb{A}}{\|}, \rho_1 \rangle \rightarrow \rho_2}$$

$$sync : \frac{\forall (u_1, (\mathbf{out}, id), g_1, c_1), (u_2, (\mathbf{in}, id), g_2, c2) \in \mathbb{A}, \forall \rho_1, \rho_2 \in val_{\mathbb{V}} \quad \neg hasUrgent_{\mathbb{A}}(\rho_1) \wedge \neg(u_1 \vee u_2) \wedge g_1(\rho_1) \wedge g_2(\rho_1) \wedge c_2(c_1(\rho_1)) = \rho_2}{\langle \underset{\mathbb{A}}{\|}, \rho_1 \rangle \rightarrow \rho_2}$$