

PROBABILISTIC ONTOLOGIES FOR EFFICIENT RESOURCE SHARING IN SEMANTIC WEB SERVICES

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OVERVIEW

- ★ Semantic Interoperability
 - ★ in the Semantic Web
 - ★ in Service Oriented Architectures
- ★ Common vs. Probabilistic Ontologies
- ★ The Role of Probabilistic Ontologies in SOA

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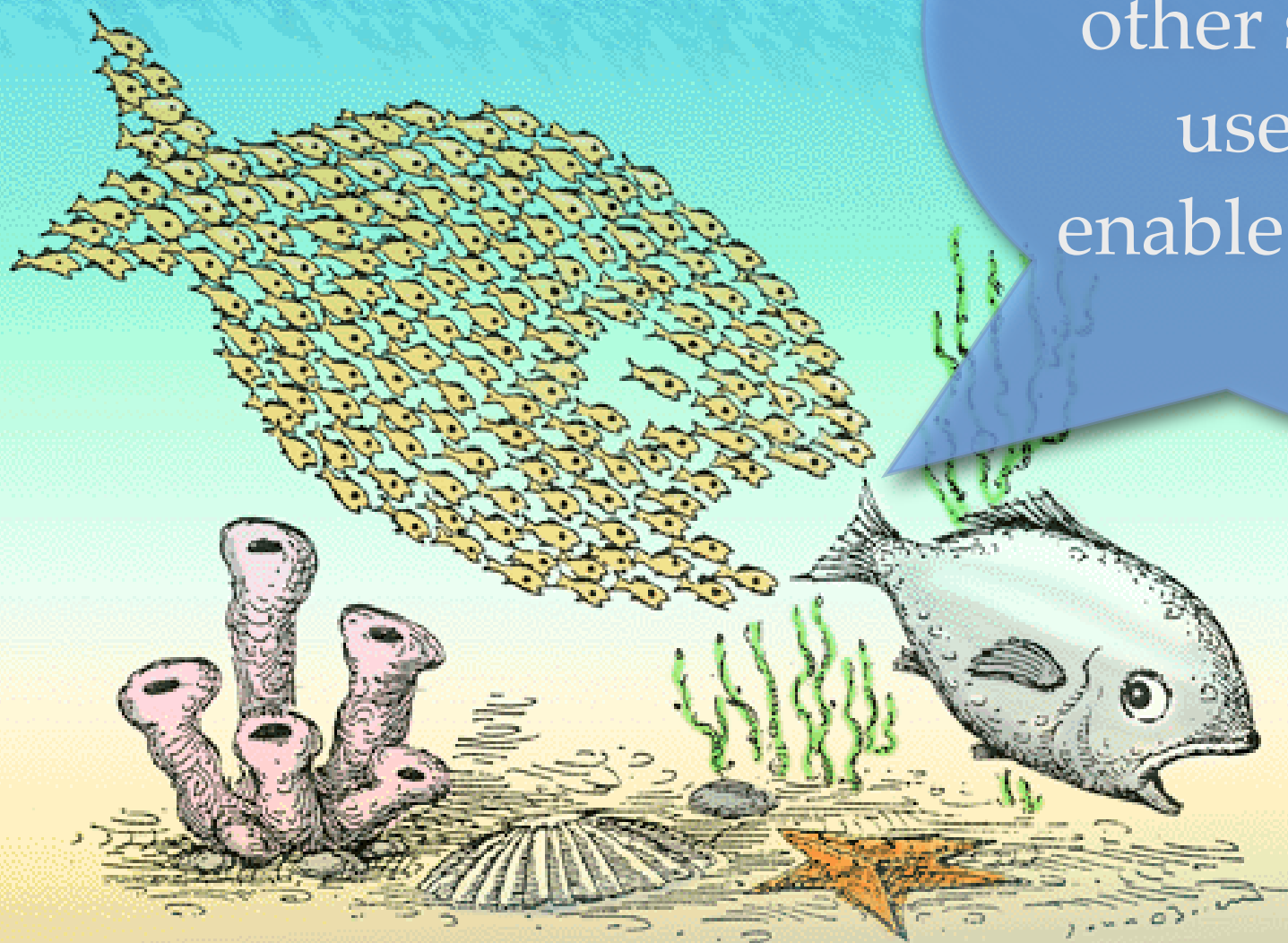
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INTEROPERABILITY?

INTEROPERABILITY?

The ability of systems, units, or forces to provide services to and accept services from other systems, units or forces and to use the services exchanged to enable them to operate effectively together.



WE NEED EXPLICIT SEMANTICS!

WE NEED EXPLICIT SEMANTICS!

“Washington voiced strong objections to the proposed policy...”

WE NEED EXPLICIT SEMANTICS!



The football team?



The University?



The State?

“Washington voiced strong objections to the proposed policy...”



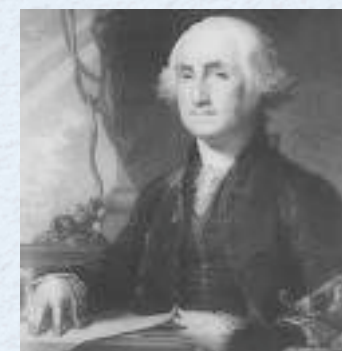
The city?



The Actor?



The Volcano?



The President?

WE NEED EXPLICIT SEMANTICS!



The football team?



The University?



The US Government?



The State?

“Washington voiced strong objections to the proposed policy...”



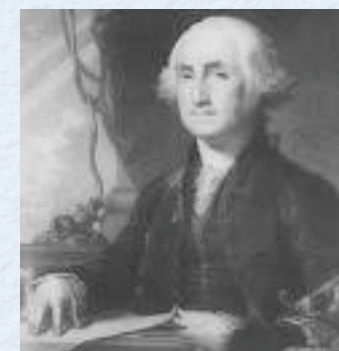
The city?



The Actor?



The Volcano?



The President?

WHY?

- ★ Essential for appropriate processing of distinct concepts that are syntactically similar
- ★ Provides the basis for rich description and reasoning
- ★ Fundamental tenet of the Semantic Web:

Adding semantics to web resources can spark a paradigm shift from information-based data exchange to knowledge-based data exchange

WHY?

- ★ Essential for appropriate processing of distinct concepts that are syntactically similar

★ **PROBLEM SOLVED!!!**

reasoning

>>> ONTOLOGIES <<<

- ★ Fundamental tenet of the Semantic Web:

SAVED THE DAY

Adding semantics to web resources can spark a paradigm shift from information-based data

exchange making people based data exchange

REALLY???

SERVICE ORIENTED ARCHITECTURE

- ★ Paradigm for information architecture design
 - ◆ Organize and utilize distributed capabilities
 - ◆ Match capabilities of providers with needs of consumers
 - ◆ Capabilities required to meet a need may cross ownership boundaries
- ★ Viewed as foundational technology for net-centric vision
 - ◆ Expected to be more scalable than traditional integration technologies
 - ◆ Expected to reduce cost of information integration within enterprise and across organizational boundaries
- ★ Web services – most common implementation

SERVICE ORIENTED ARCHITECTURE

Web Services Architecture Usage Scenarios

http://www.w3.org/TR/ws-arch-scenarios/

Web Services Description Language (WSDL) Version 2.0 SOAP 1.1 Binding

http://www.w3.org/TR/2006/WD-wsdl20-soap11-binding-20060327/

Web Services Architecture Usage Scenarios

http://www.w3.org/TR/ws-arch-scenarios/

Web Services

http://www.w3.org/2002/ws/

WSDL 2.0 Interop Event

http://www.w3.org/2002/ws/2006/07/interop-logistic.html

W3C Architecture domain Web Services Activity

Interoperability Event on WSDL 2.0

Call for Participation

July 5-7, 2006
[IBM Toronto Software Lab](#), Toronto, Canada.

Goal

The goal of this WSDL 2.0 interoperability event is to:

- Improve the test suite
- Exchange implementations feedback
- Test WSDL 2.0 implementations against the test suite
- Gather feedback and report for the purpose of the W3C Candidate Recommendation phase

Meeting Registration

W3C Working Group Note

W3C Working Draft

W3C Working Group Note

W3C Working Group Note

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- reliabili
- trust me
- descrip

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SERVICE ORIENTED ARCHITECTURE

Web Services - Semantic Web - slide "Conclusion"

http://www.w3.org/2003/Talks/0521-www-keynote-tbl/slide36-0.html

W3C[®]

Conclusion

Web services and semantic web are building out rapidly from the URI-HTTP-XML base.

While they are being developed independently, they will merge naturally and strengthen each other as development continues.

Web Services meet immediate need.

Semantic Web has exponential growth potential

Tim Berners-Lee

36 of 37

Meeting Registration

W3C Working Group Note

ProgCinemas CESPE/UnB - PAS Proz.com Legislação MEBN Group PC Direito Cacau Jus Navigandi Proz web News (268)

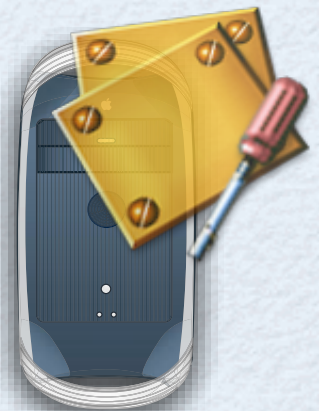
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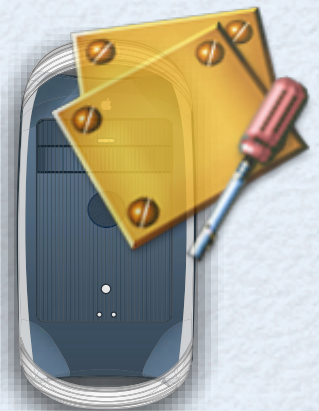
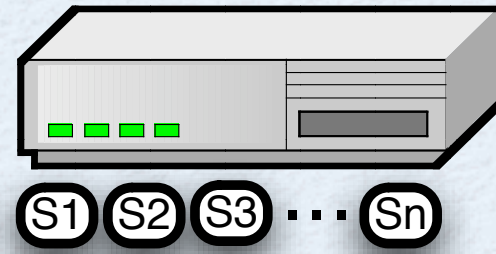
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WEB SERVICES?

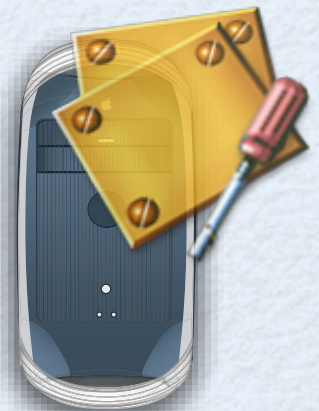
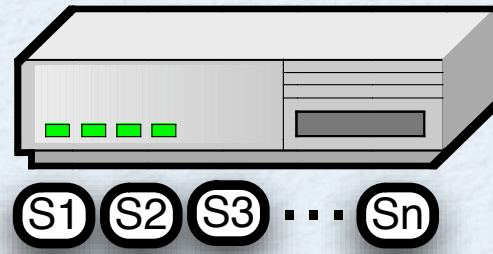
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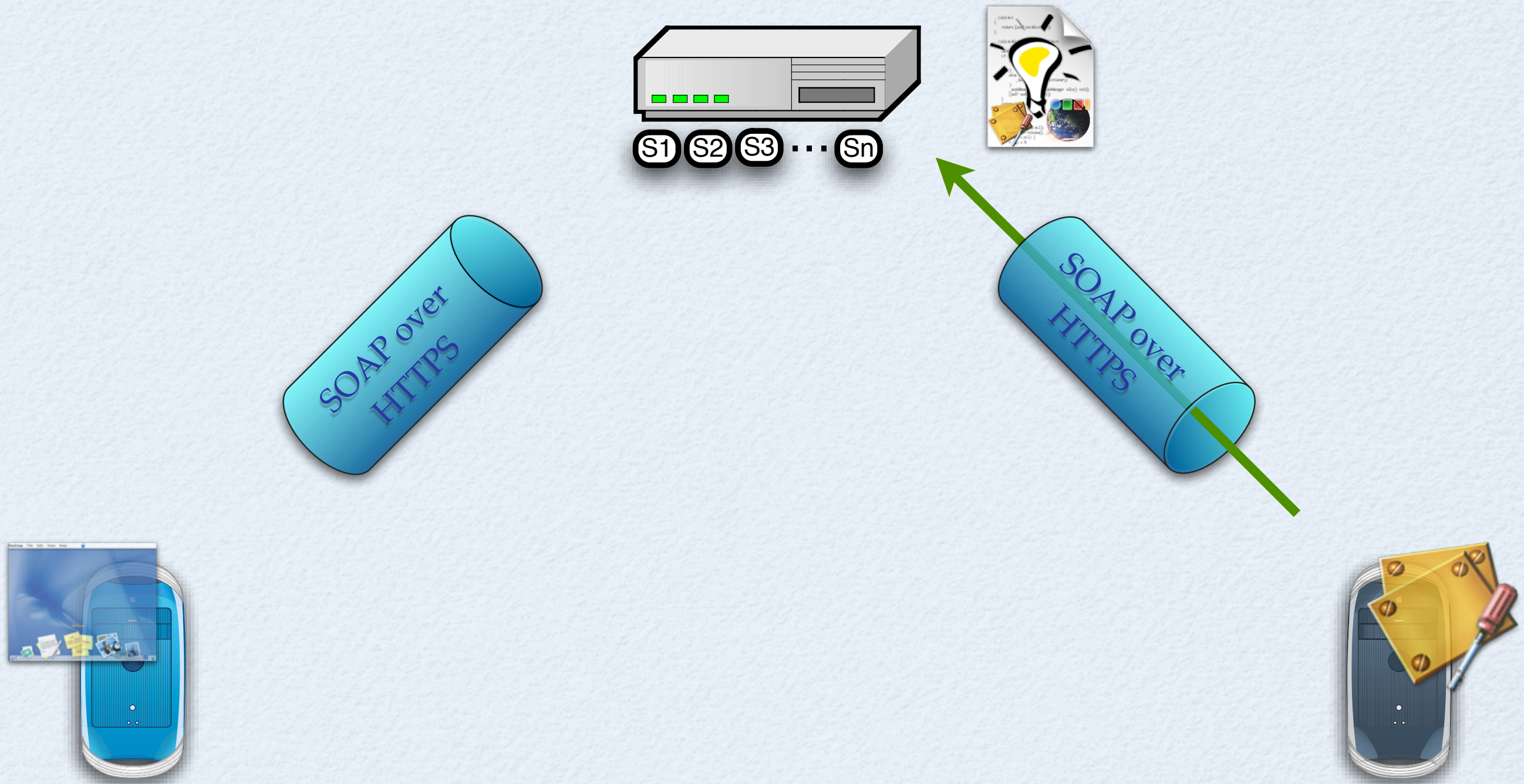
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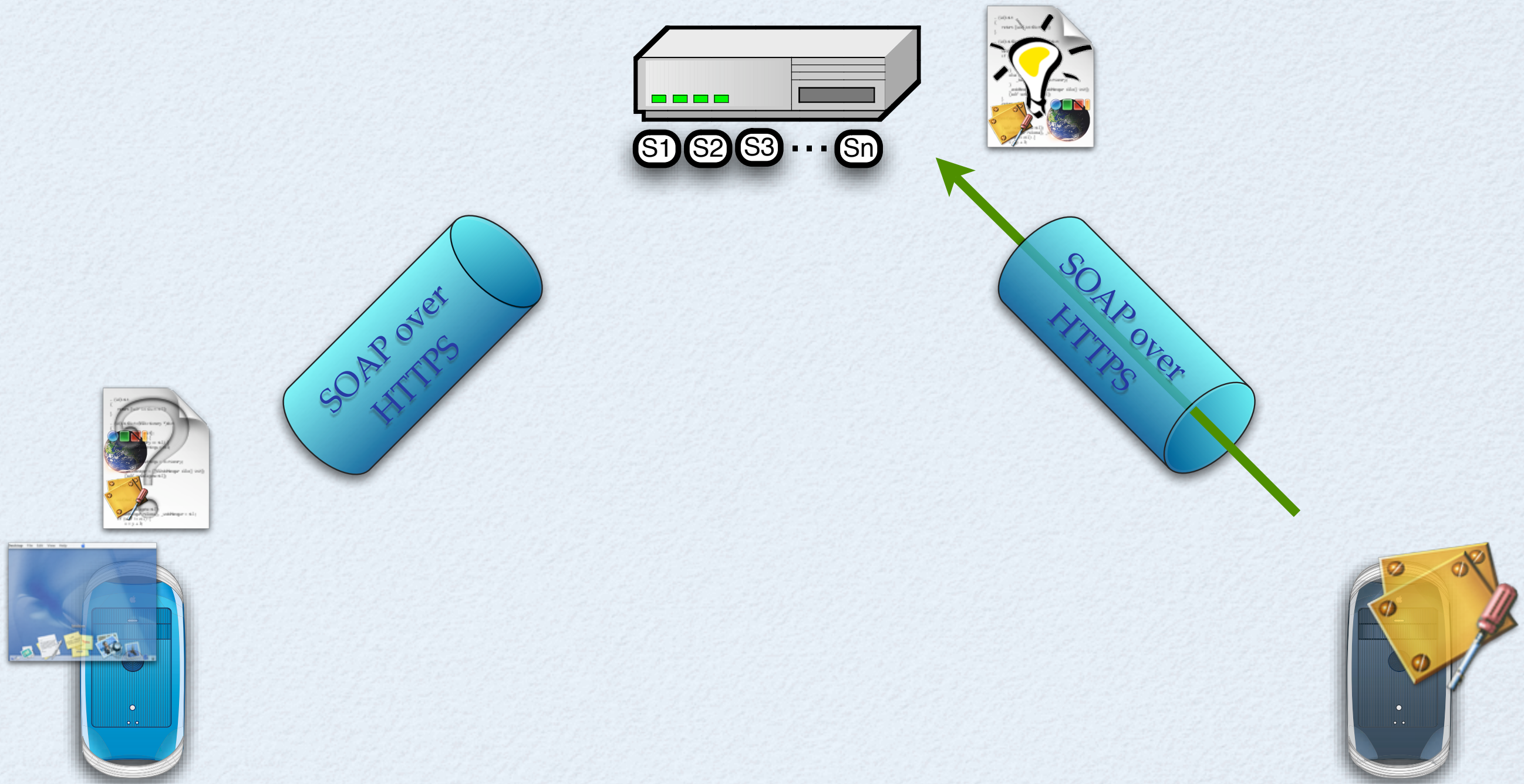
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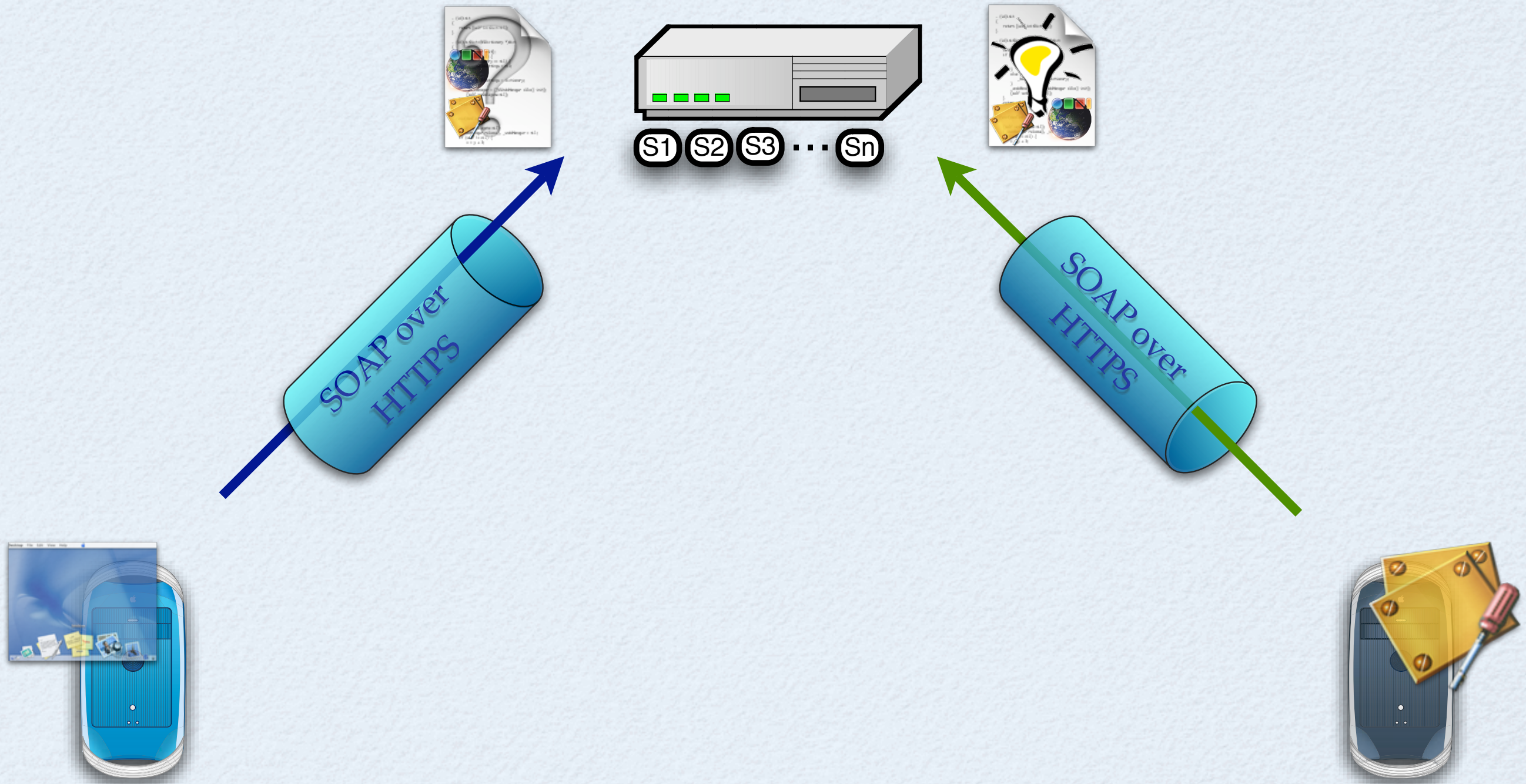
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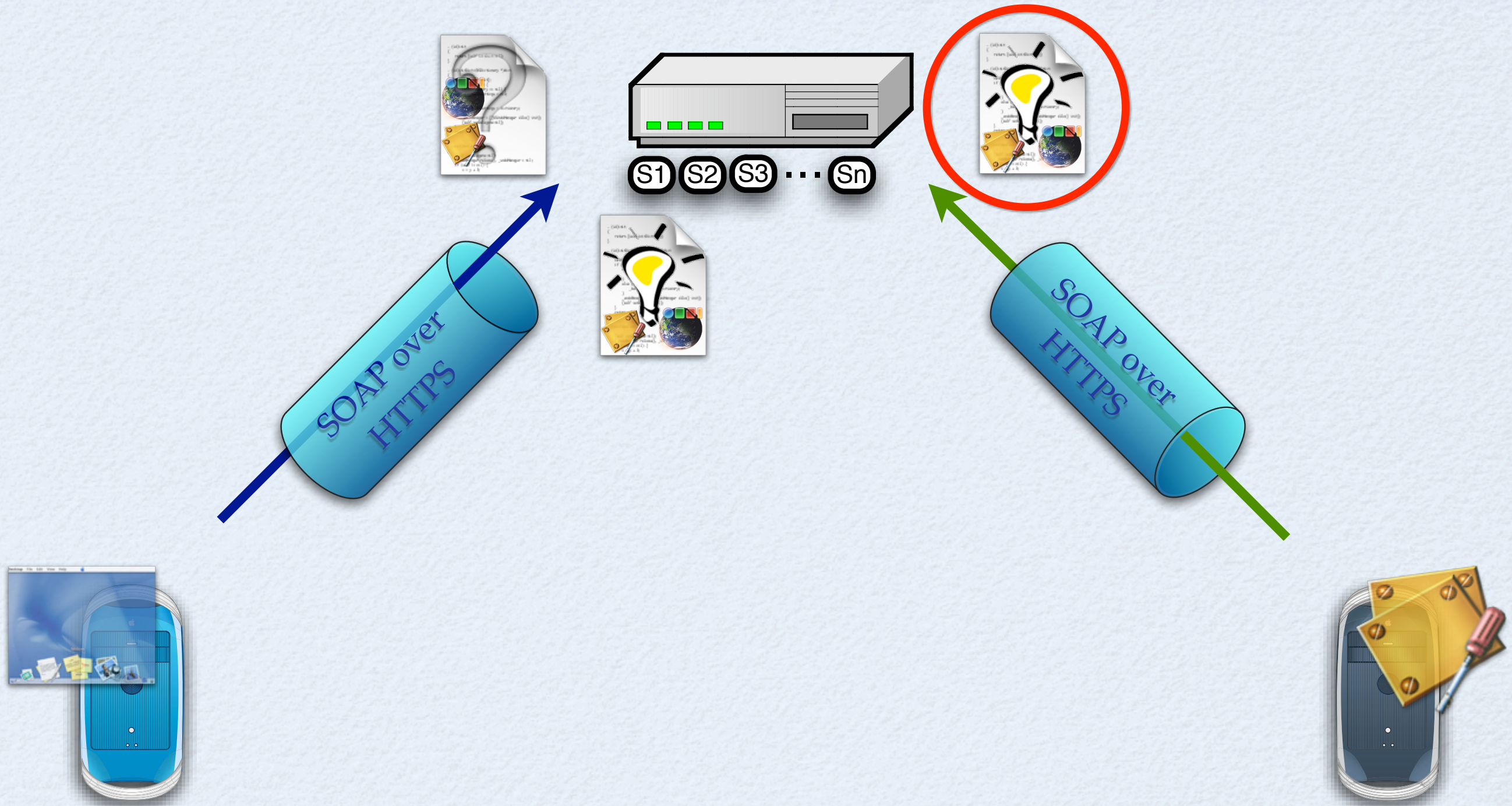
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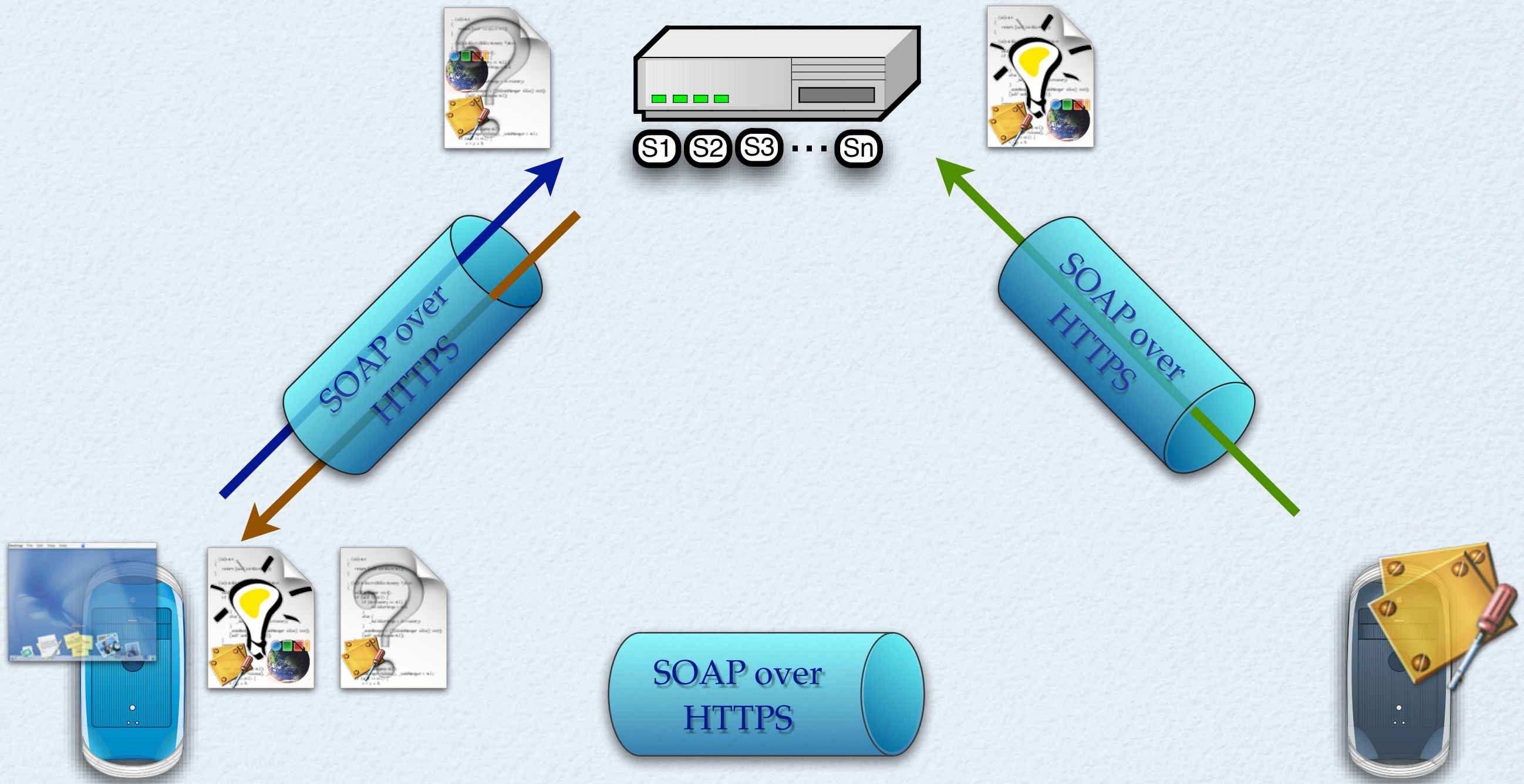
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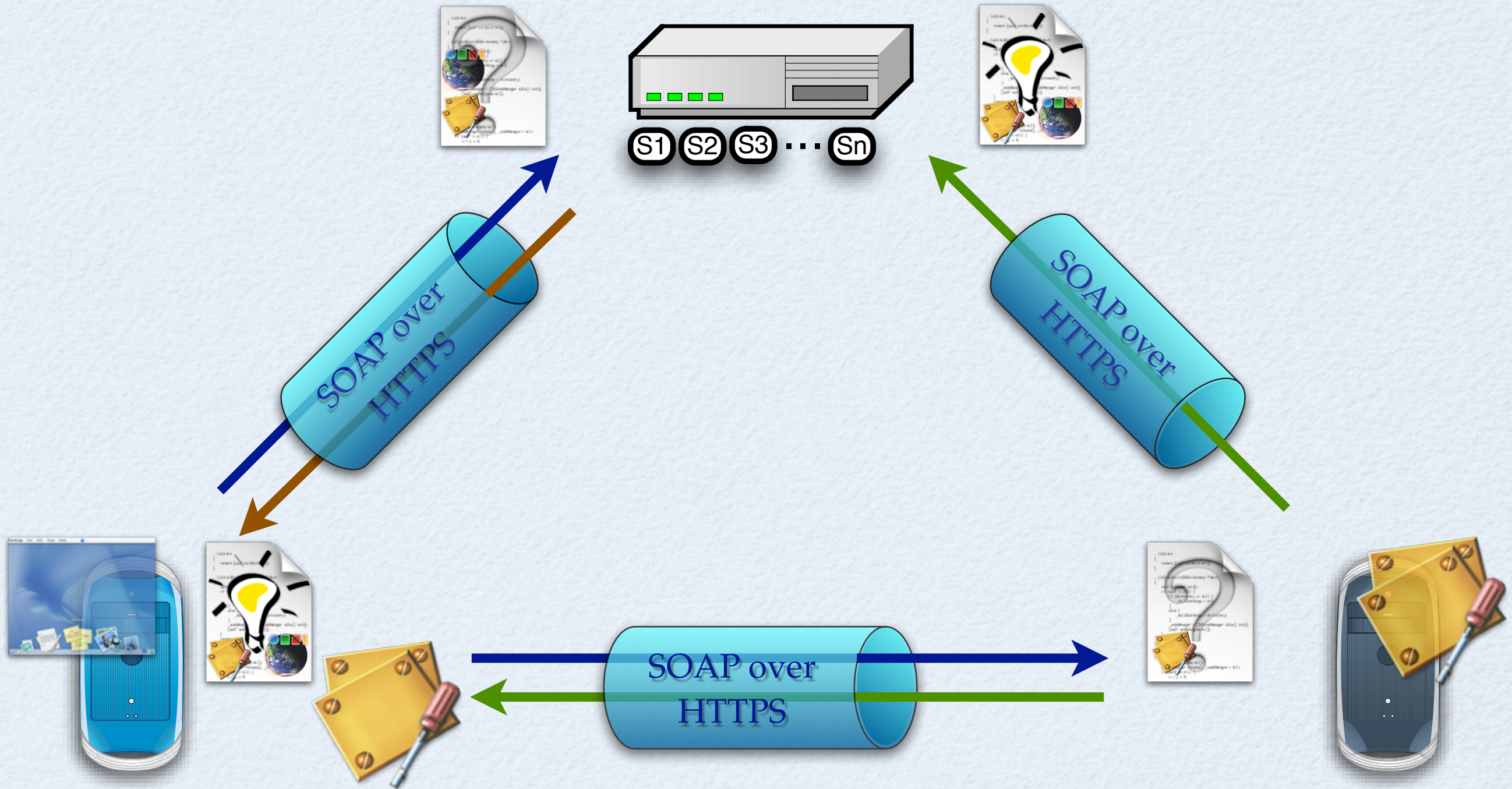
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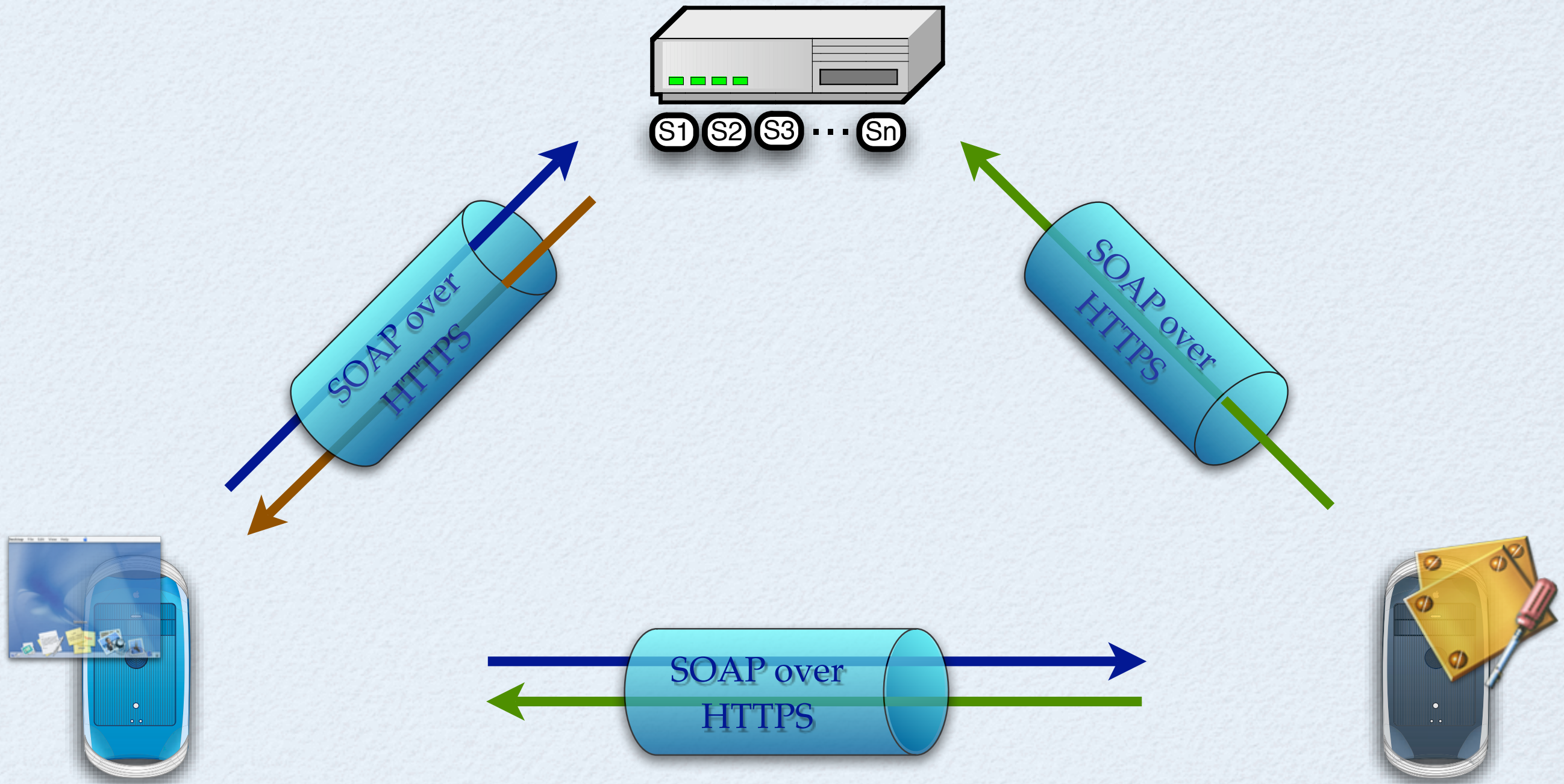
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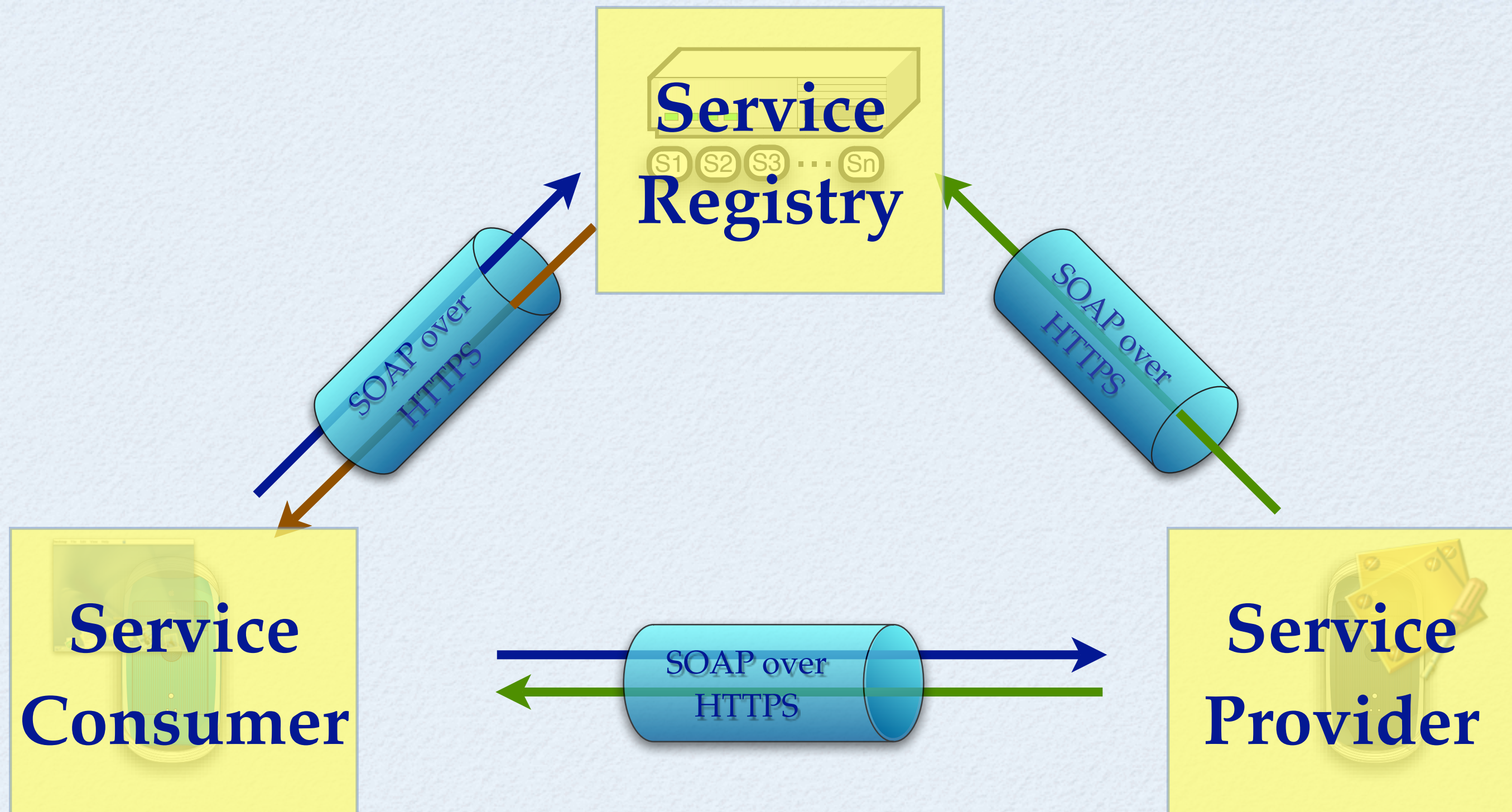
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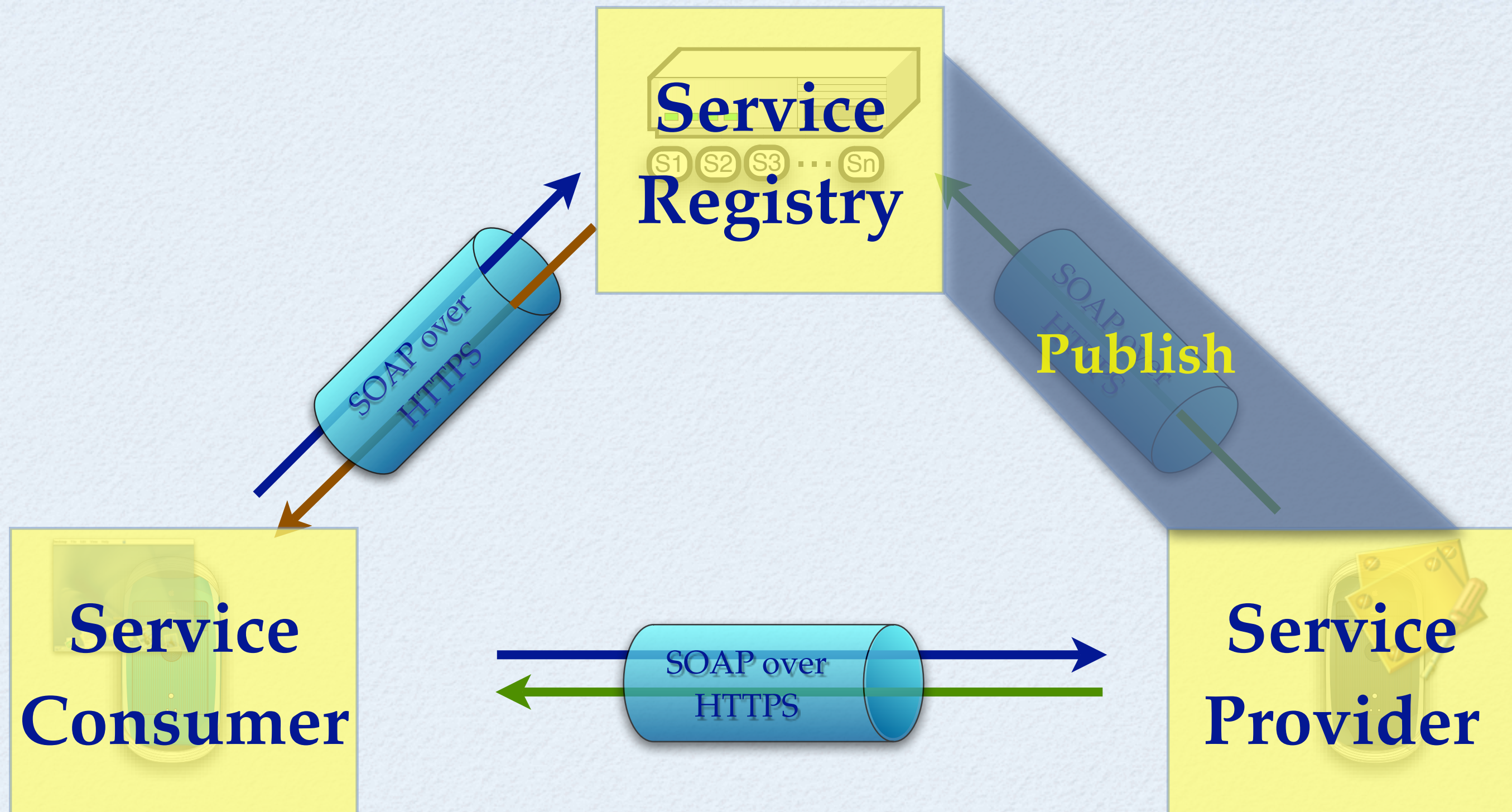
THE P-F-B TRIANGLE



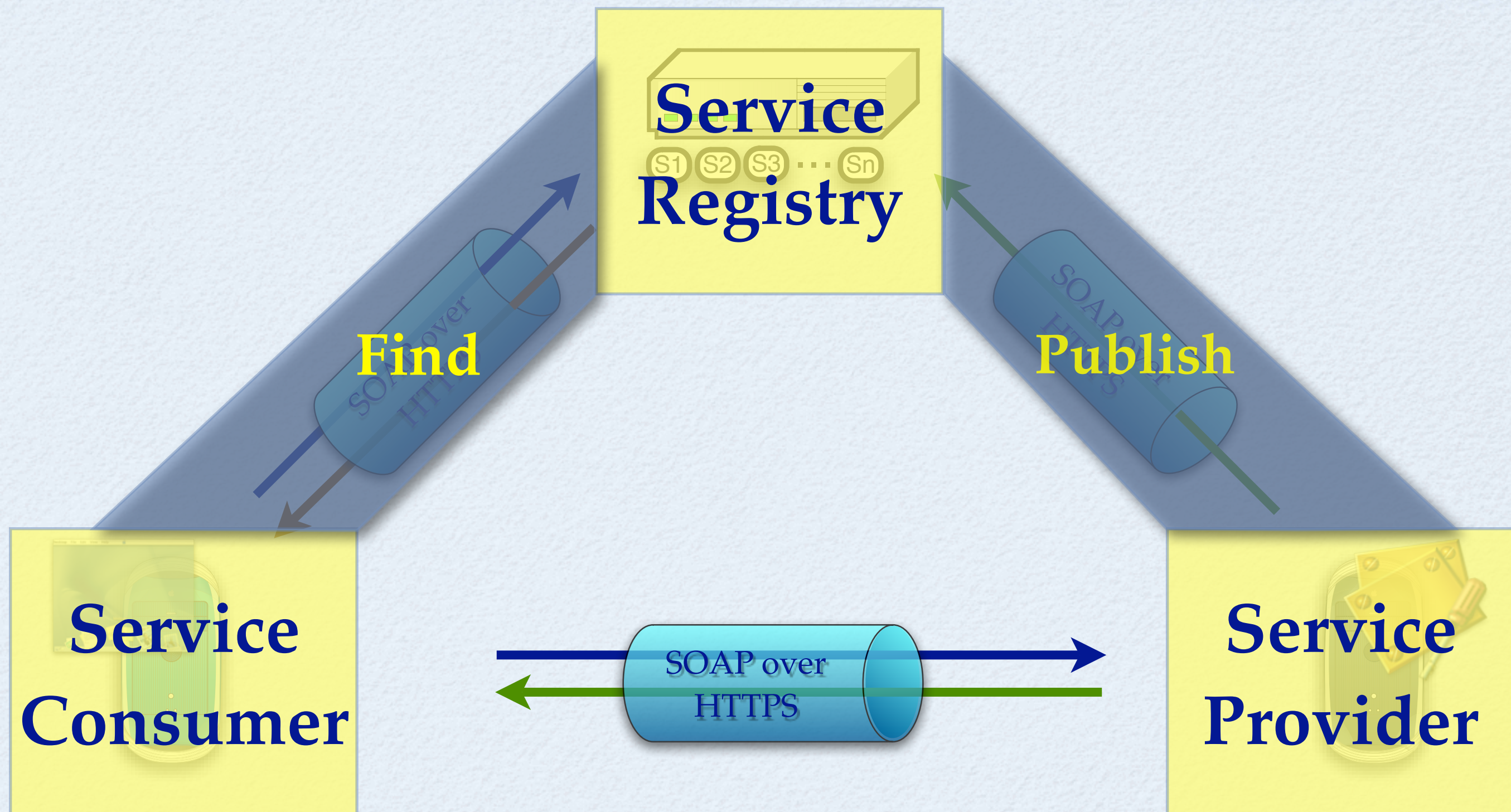
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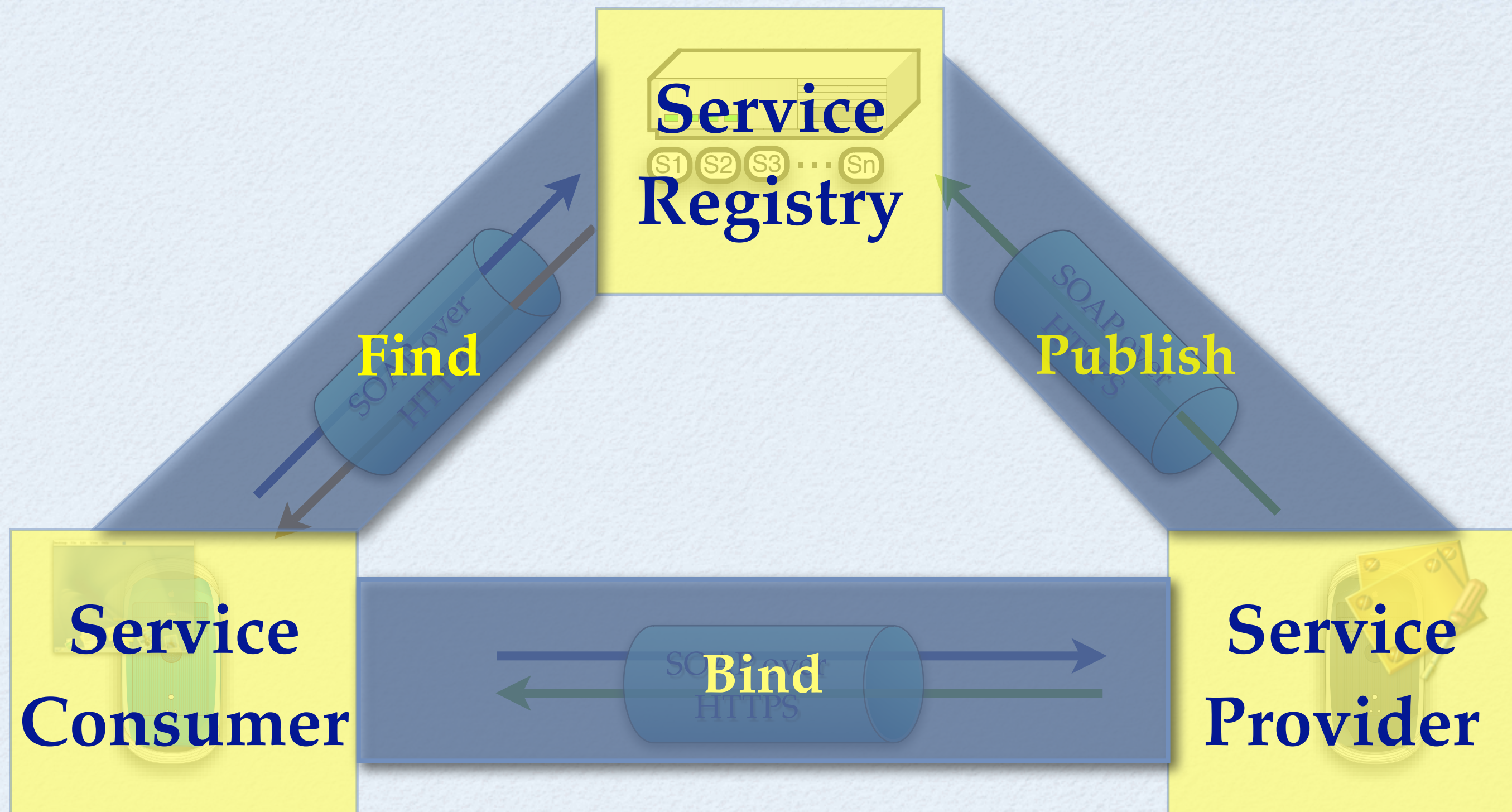
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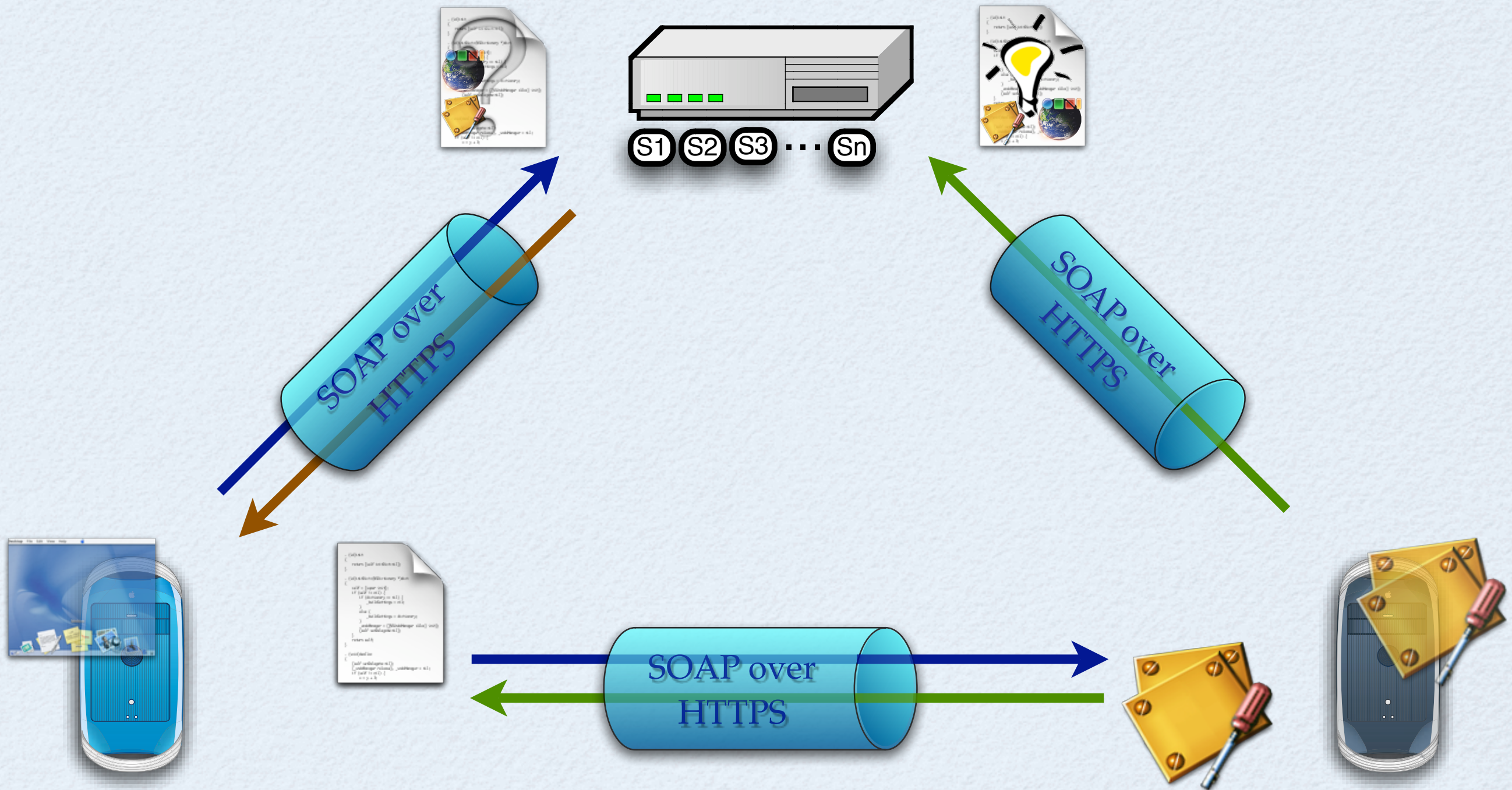
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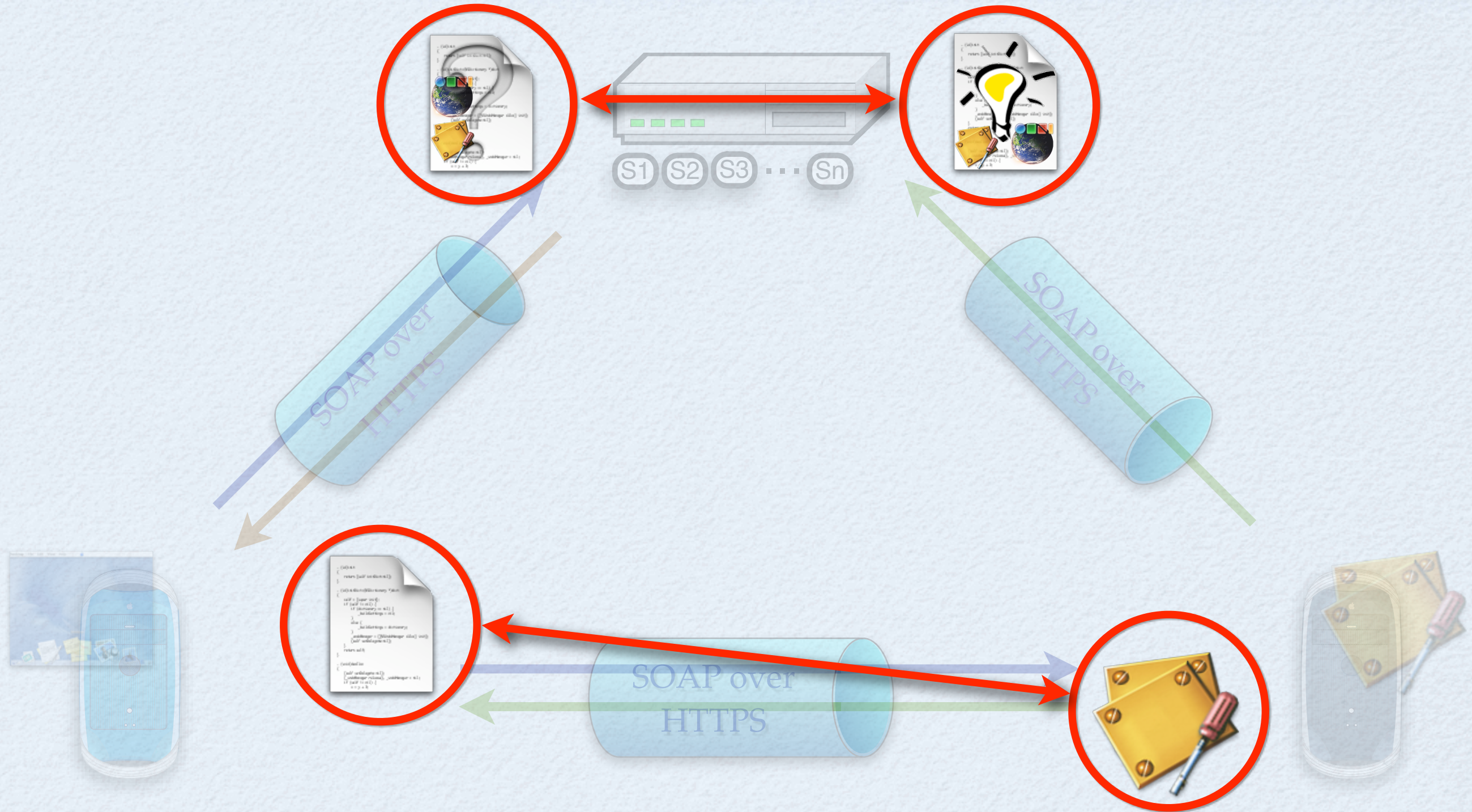
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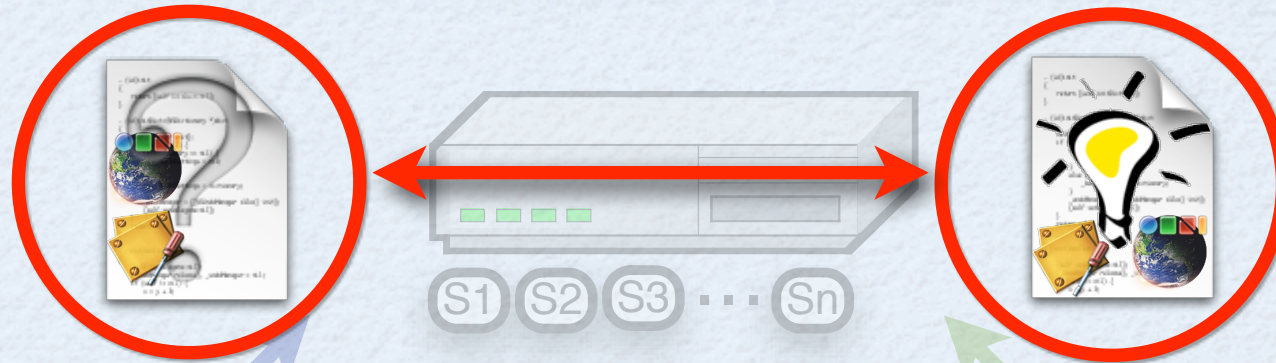
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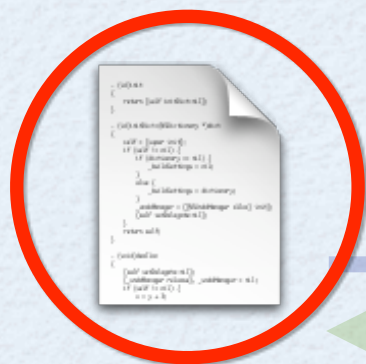


• Syntax

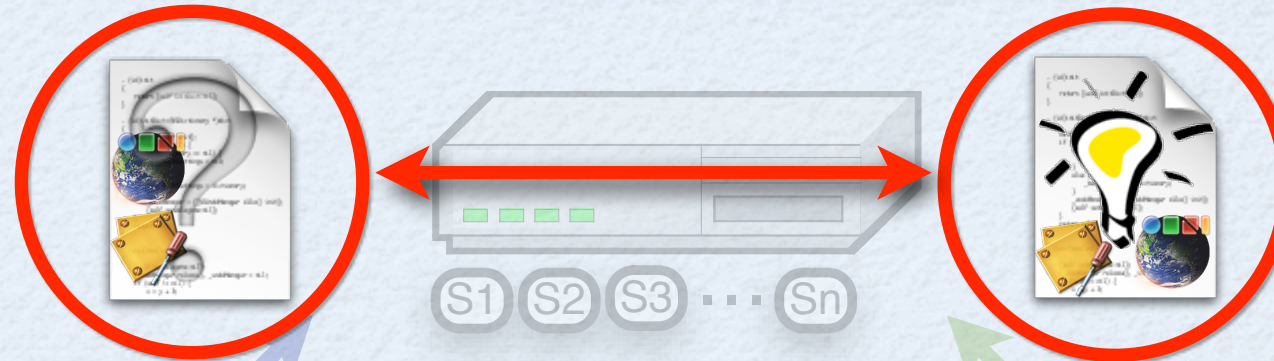
- Syntax means rules of formation for a data type
- Syntactic interoperability means an application can process the data formats produced by another
- E.g., 38.2 is a legal floating point number

• Semantics

- Semantics is the meaning of the expressions
- Semantic interoperability means applications interpret the data in the same way
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DO WE NEED SEMANTICS?

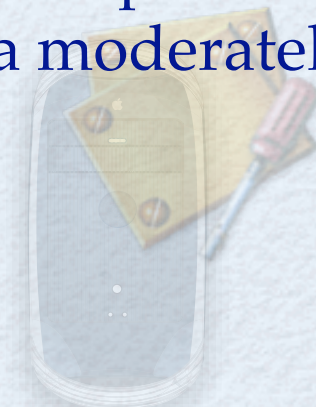
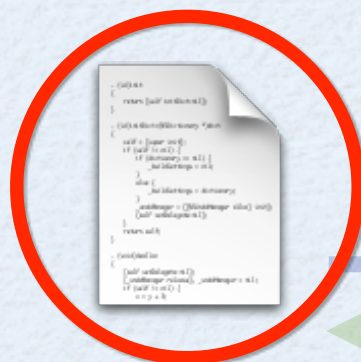


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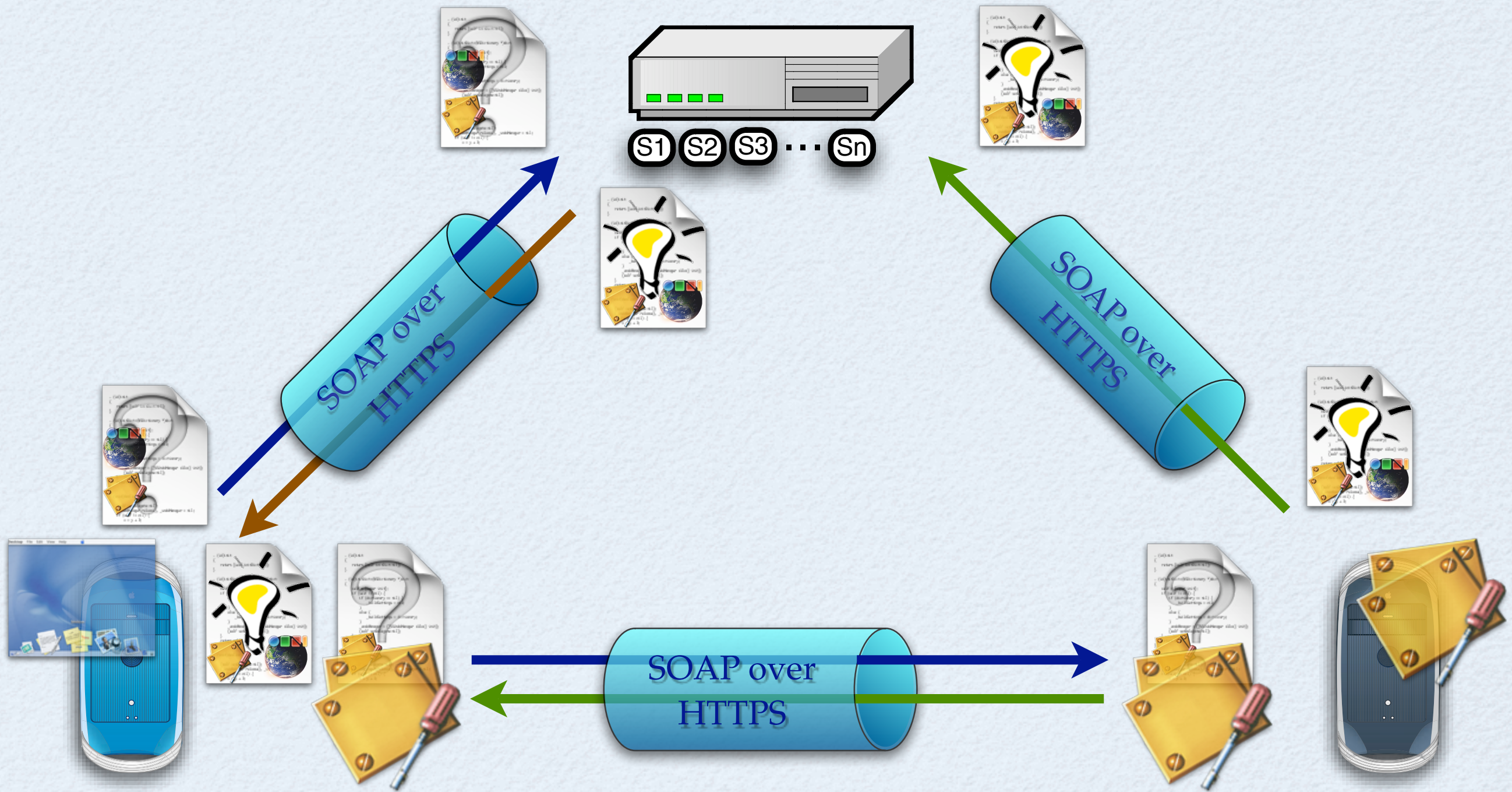
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- Consumers and providers need to agree on semantics of service descriptions
- Semantic interoperability is a much stronger requirement than type consistency



SEMANTICS IN SOA

★ Description

- * What does the service do?
- * What are conditions (constraints / policies) for use?
- * How to use it? (Address & WSDL)

★ Ontology

- * Formal, computable description of entities in a domain, relations between them, processes in which they participate, attributes they can have
- * Controlled vocabulary and grammar
- * Intended to facilitate knowledge sharing

SEMANTICS IN SOA

OWL-S: Semantic Markup for Web Services

http://www.daml.org/services/owl-s/1.0/owl-s.html

3 An Upper Ontology for Services

Our structuring of the ontology of services is motivated by the need to provide three essential types of knowledge about a service (shown in figure 1), each characterized by the question it answers:

- *What does the service require of the user(s), or other agents, and provide for them?* The answer to this question is given in the "profile". Thus, the class SERVICE presents a SERVICEPROFILE
- *How does it work?* The answer to this question is given in the "model." Thus, the class SERVICE is describedBy a SERVICEMODEL
- *How is it used?* The answer to this question is given in the "grounding." Thus, the class SERVICE supports a SERVICEGROUNDING.

The class SERVICE provides an organizational point of reference for declaring Web services; one instance of SERVICE will exist for each distinct published service. The properties *presents*, *describedBy*, and *supports* are properties of SERVICE. The classes SERVICEPROFILE, SERVICEMODEL, and SERVICEGROUNDING are the respective ranges of those properties. Each instance of SERVICE will *present* a descendant class of SERVICEPROFILE, be *describedBy* a descendant class of SERVICEMODEL, and *support* a descendant class of SERVICEGROUNDING. The details of profiles, models, and groundings may vary widely from one type of service to another—that is, from one descendant class of SERVICE to another. But each of these three classes provides an essential type of information about the service, as characterized in the rest of the paper.

```
graph TD; Resource([Resource]) -- provides --> Service([Service]); Service -- presents --> ServiceProfile([ServiceProfile]); Service -- DescribedBy --> ServiceModel([ServiceModel]); Service -- supports --> ServiceGrounding([ServiceGrounding]);
```

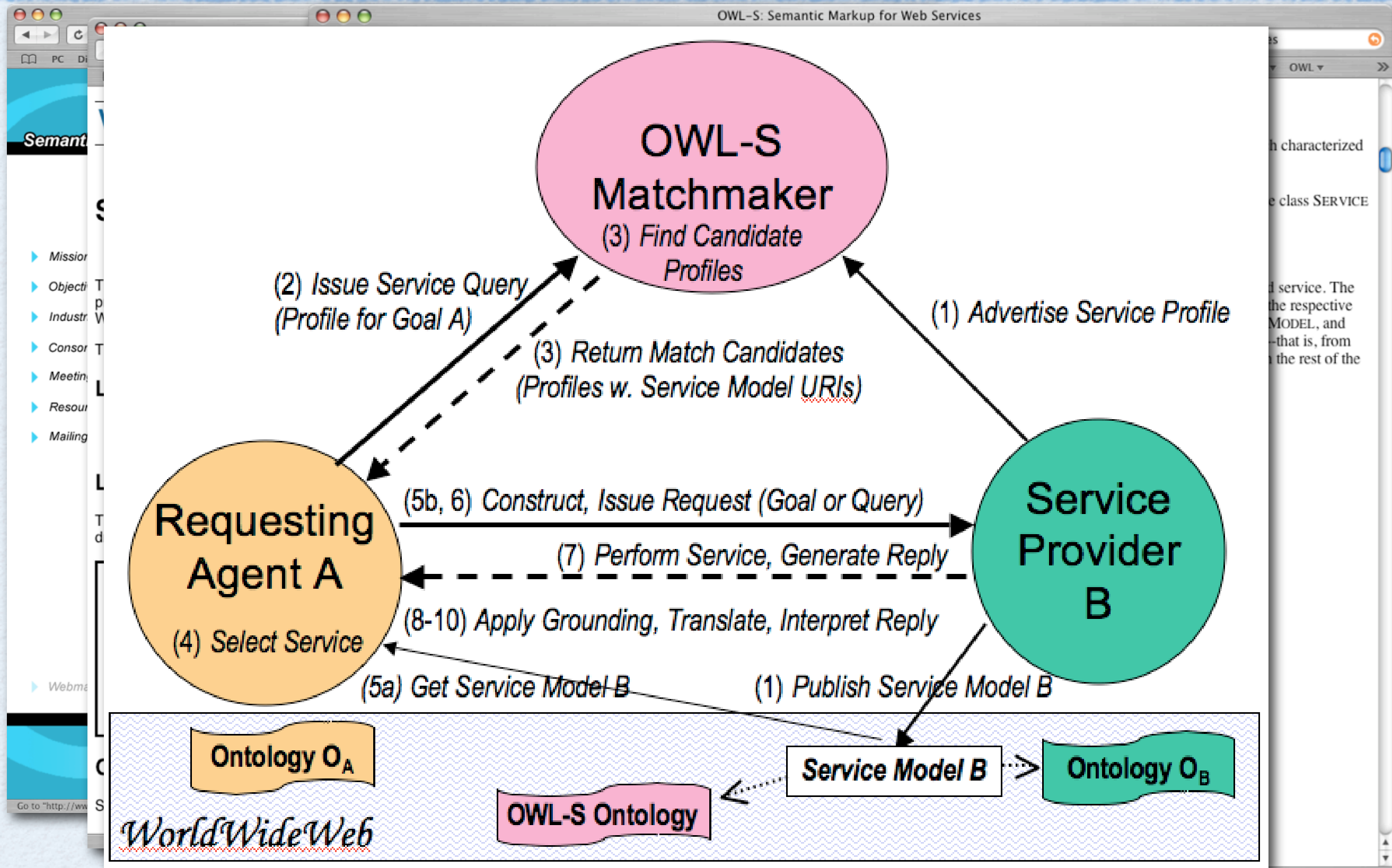
What the service does

How it works

How to access it

Figure 1: Top level of the service ontology

SEMANTICS IN SOA



SEMANTICS IN SOA

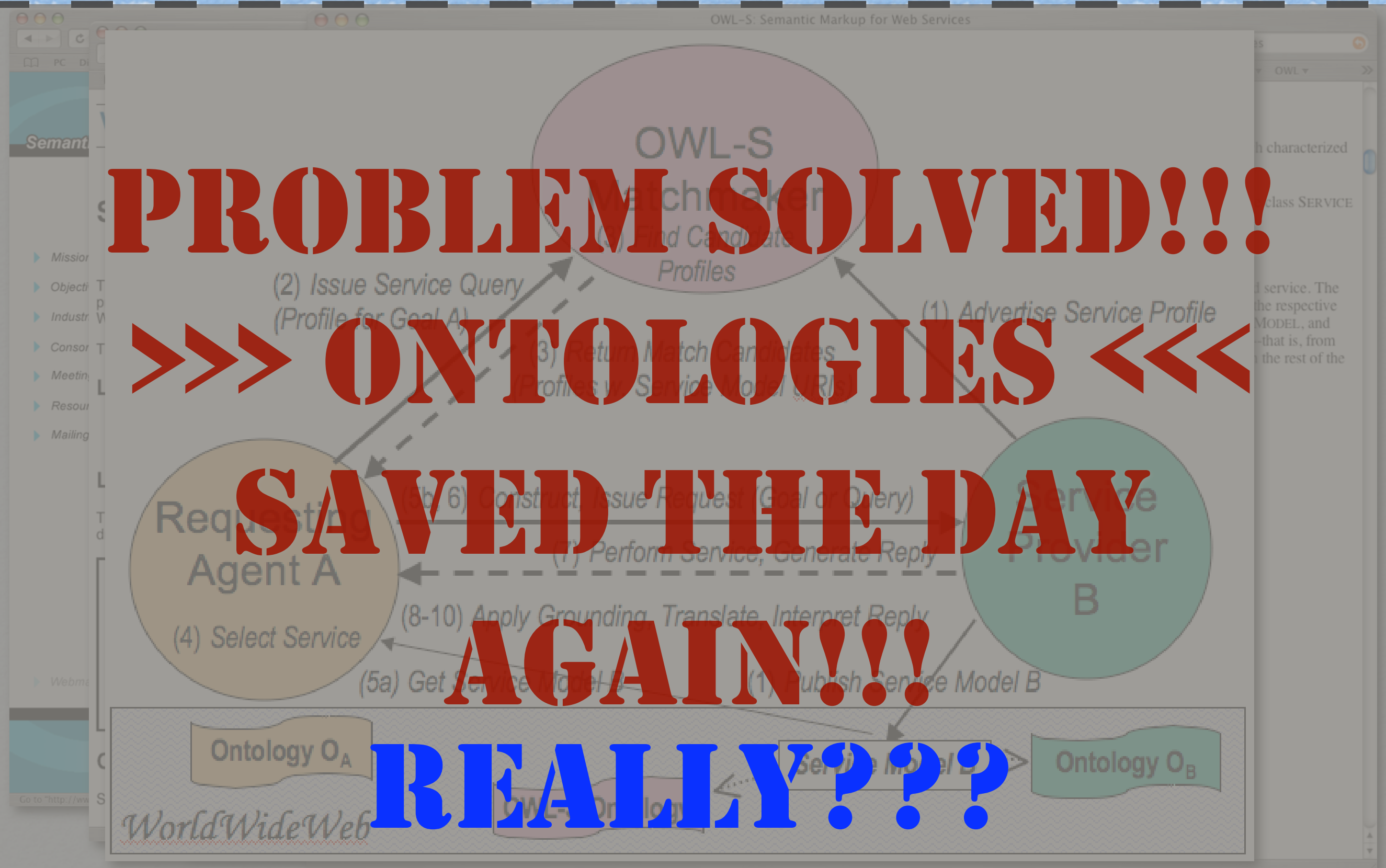
PROBLEM SOLVED!!!

>>> ONTOLOGIES <<<

SAVED THE DAY

AGAIN!!!

REALLY???



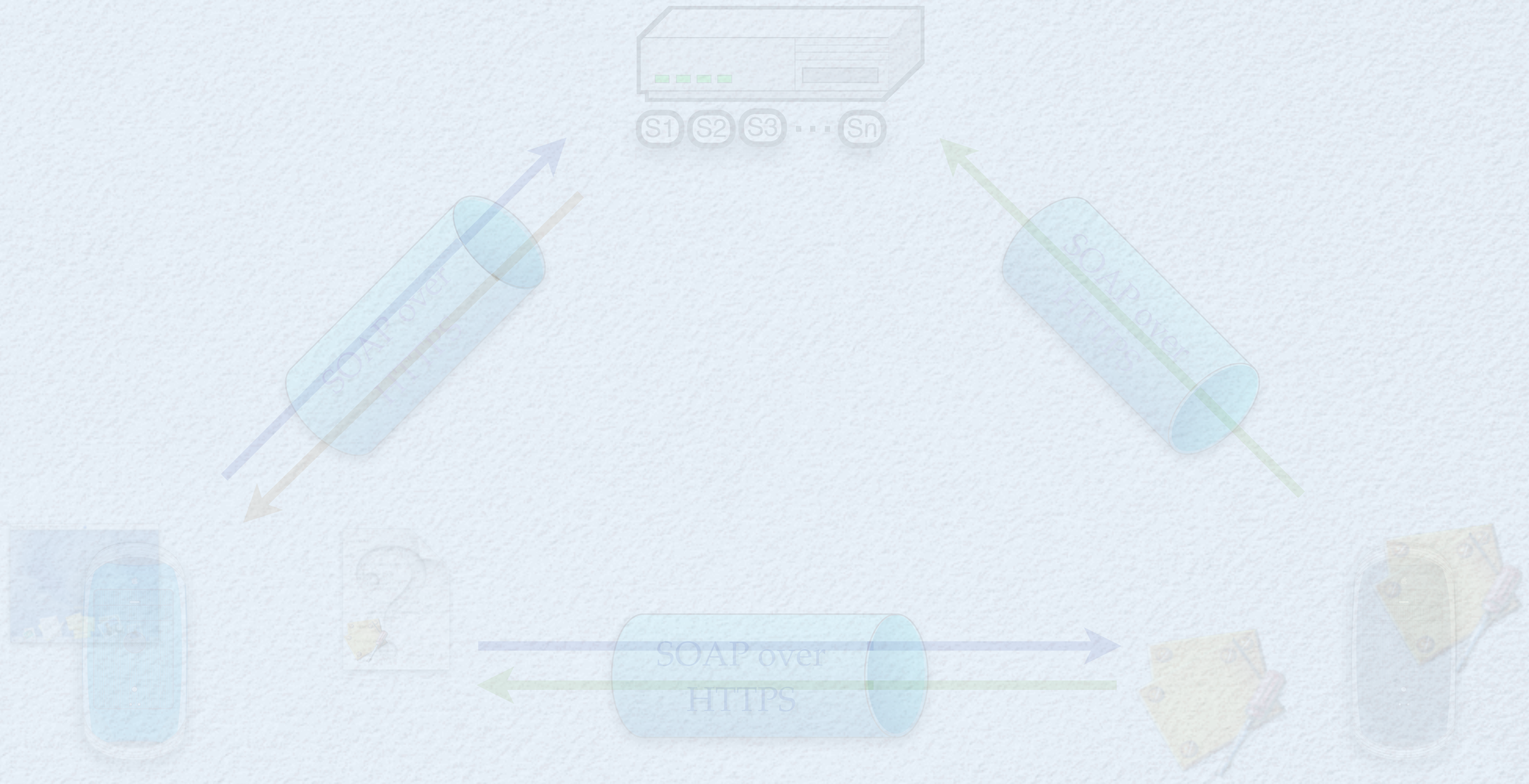
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WHY UNCERTAINTY IN SOA?



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★ Finding and binding processes

- * Systems in a heterogeneous world have different ontologies
- * Exact translation of terms may not be possible
- * Legacy systems have no formal representation of semantics



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Matching a capability to a need is a problem in inference and decision making under uncertainty

WHY UNCERTAINTY IN SOA?

★ Finding and binding processes **CAN BE**

* Systems in a heterogeneous world have different ontologies **PROBLEM SOLVED!!!**

* Exact translation of terms may not be possible **PROBABILISTIC**

* Legacy systems have no formal representation of semantics **>>> ONTOLOGIES <<<**

CAN HELP TO

SAVE X THE DAY

Matching capability to need is a problem in inference and decision making under uncertainty

ONTOLOGIES

ONTOLOGIES

Definition: An ontology is an explicit, formal representation of knowledge about a domain of application. This includes:

- a) Types of entities that exist in the domain;
- b) Properties of those entities;
- c) Relationships among entities;
- d) Processes and events that happen with those entities;

where the term entity refers to any concept (real or fictitious, concrete or abstract) that can be described and reasoned about within the domain of application. ■

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PROBABILISTIC ONTOLOGIES

Definition: A **probabilistic ontology** is an explicit, formal representation of knowledge about a domain of application. This includes:

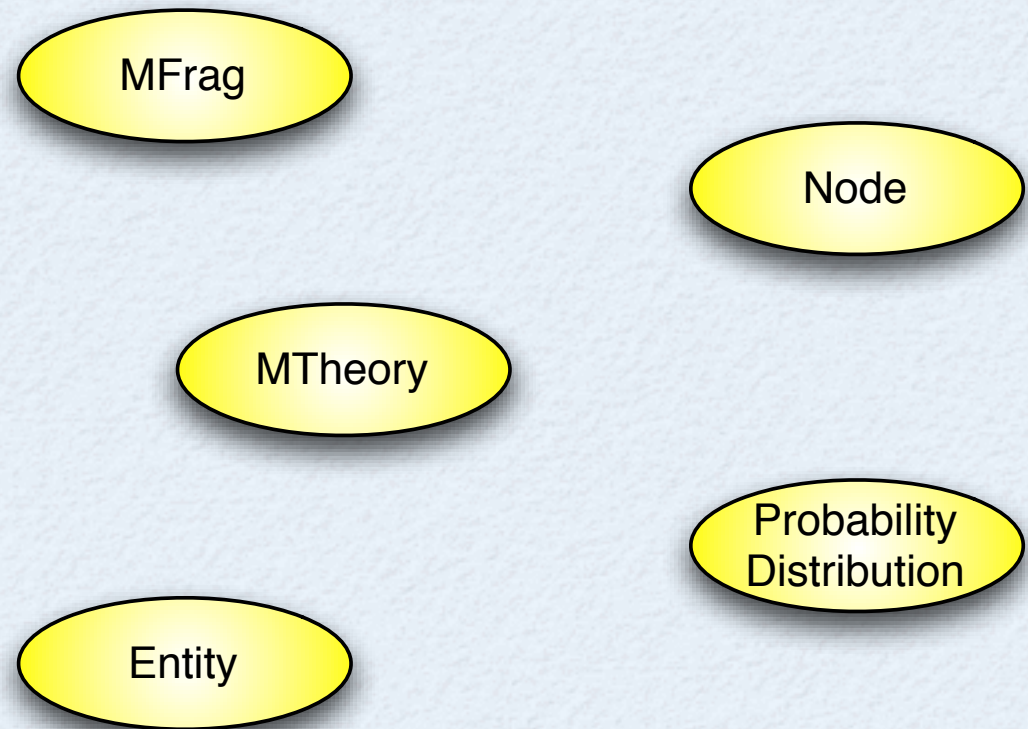
- a) Types of entities that exist in the domain;
- b) Properties of those entities;
- c) Relationships among entities;
- d) Processes and events that happen with those entities;
- e) Statistical regularities that characterize the domain;
- f) Inconclusive, ambiguous, incomplete, unreliable, and dissonant evidence related to entities of the domain;
- g) Uncertainty about all the above forms of knowledge;





where the term entity refers to any concept (real or fictitious, concrete or abstract) that can be described and reasoned about within the domain of application. ■

PR-OWL

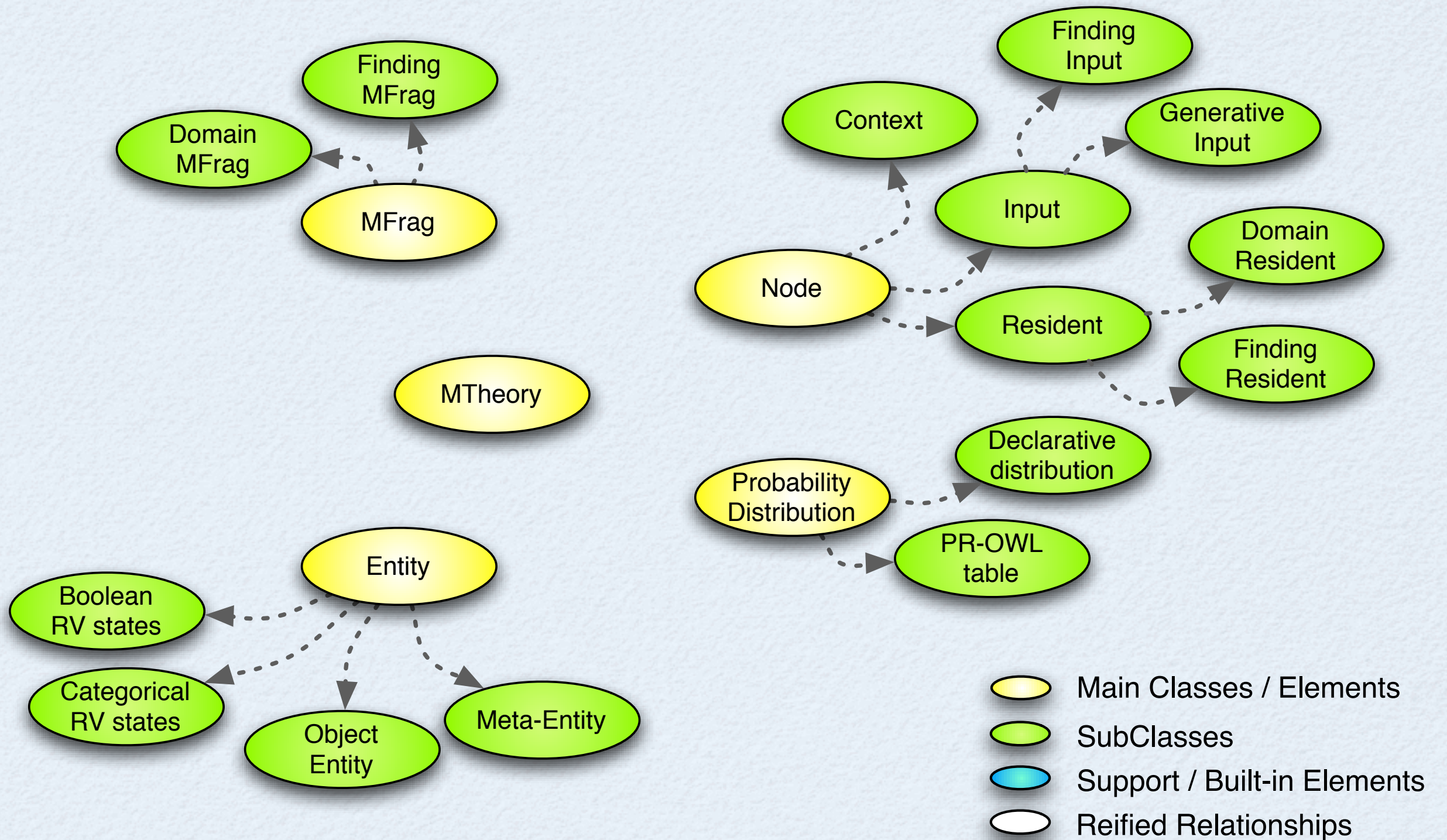
-  Main Classes / Elements
-  SubClasses
-  Support / Built-in Elements
-  Reified Relationships

PR-OWL

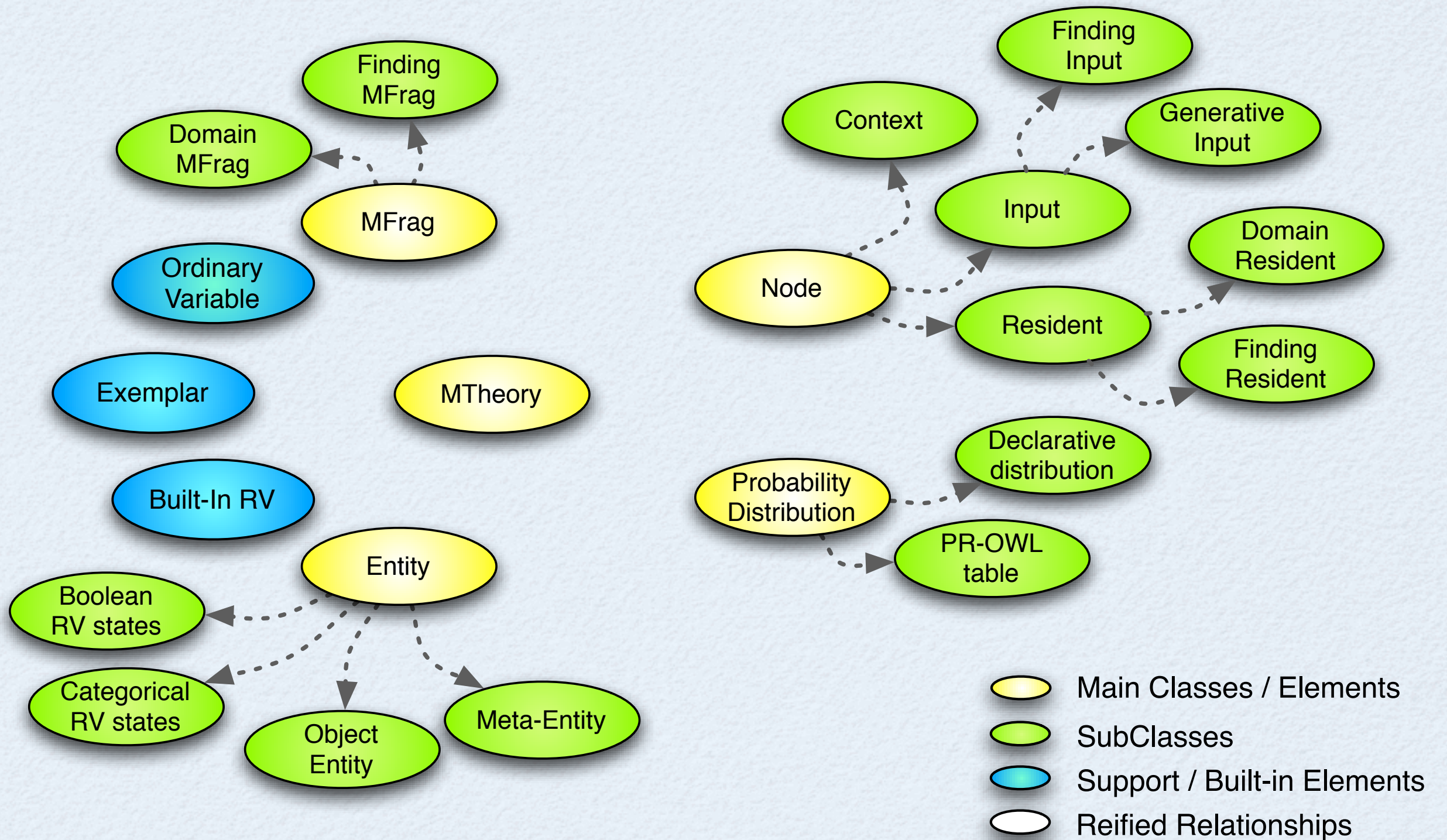


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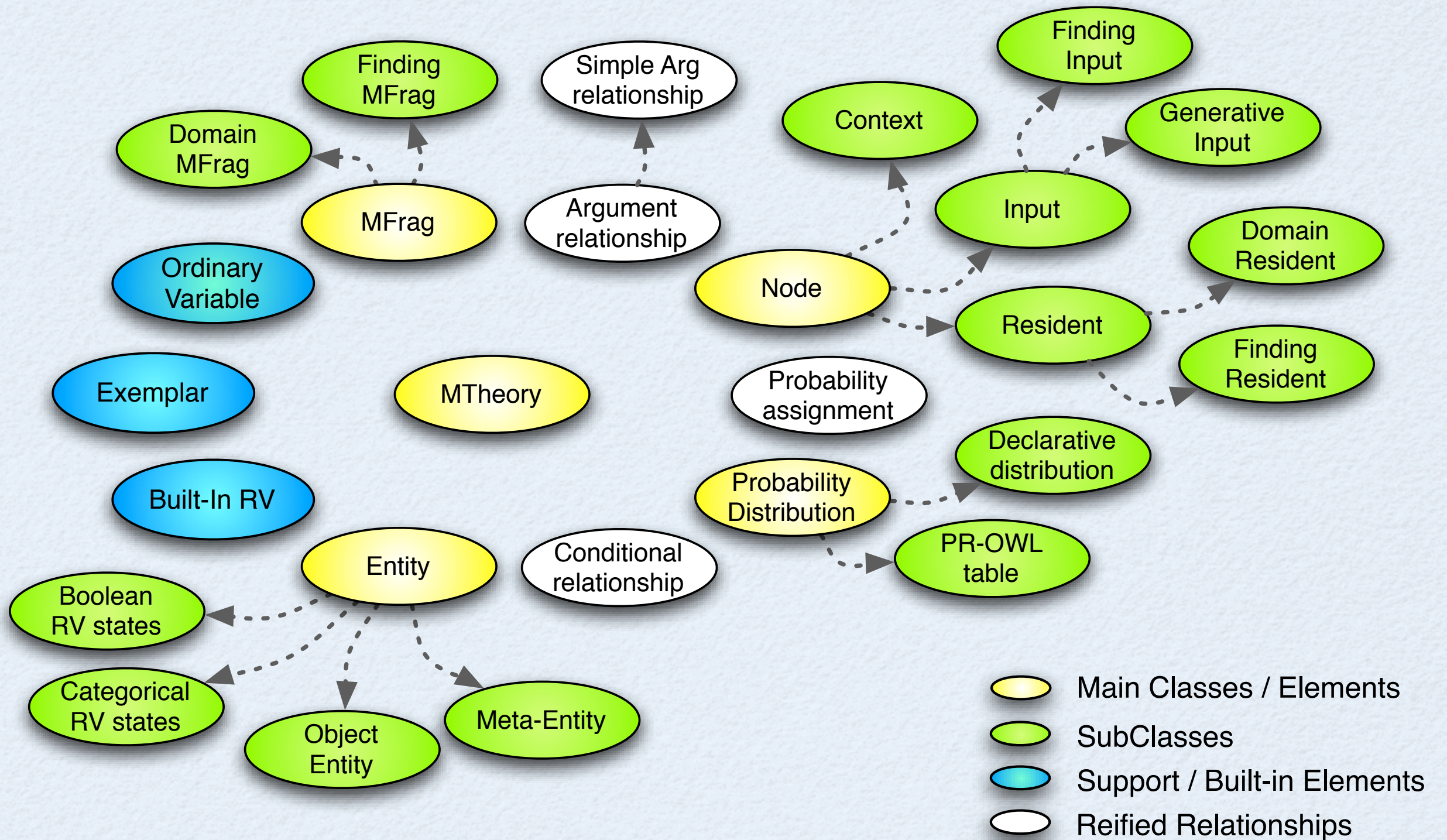
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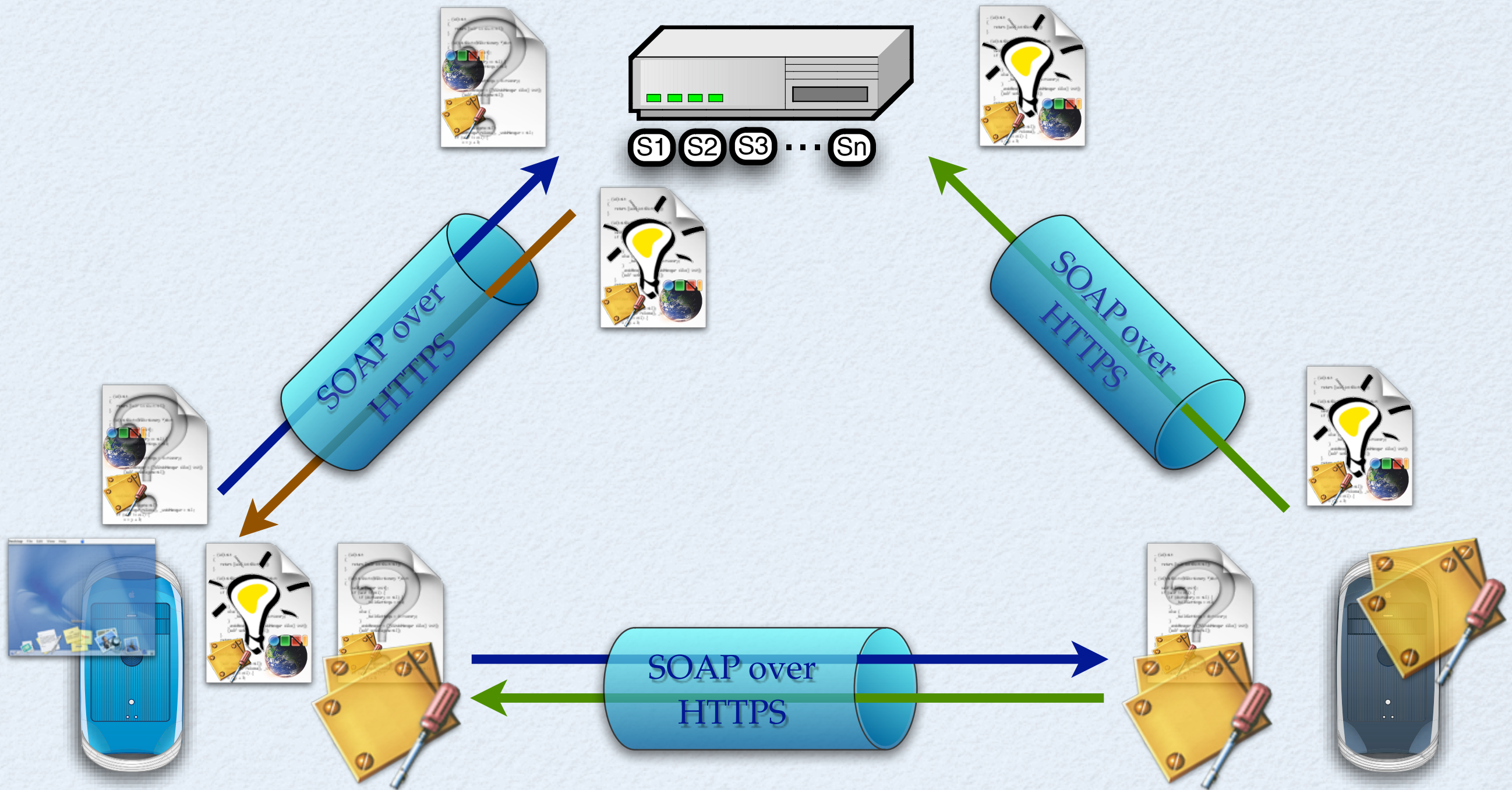
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THE EXECUTION CONTEXT



THE EXECUTION CONTEXT

Security

Quality of Service
S1 S2 S3 ... Sn

Identify Best Provider

Legacy Descriptions

Vocabulary

Combining Services

Licensing

Protocols

Matching the Values

Authentication

THE EXECUTION CONTEXT

- ★ All those aspects have some sort of uncertainty involved!
- ★ Addressing them without a principled means for representing uncertainty is a recipe for failure!

PROBABILISTIC ONTOLOGIES IN SOA

- ★ The above questions do not have simple, universally valid answers
- ★ Deterministic approaches will not suffice to build viable solutions to all of them
- ★ Probabilistic ontologies can help to bridge the gap

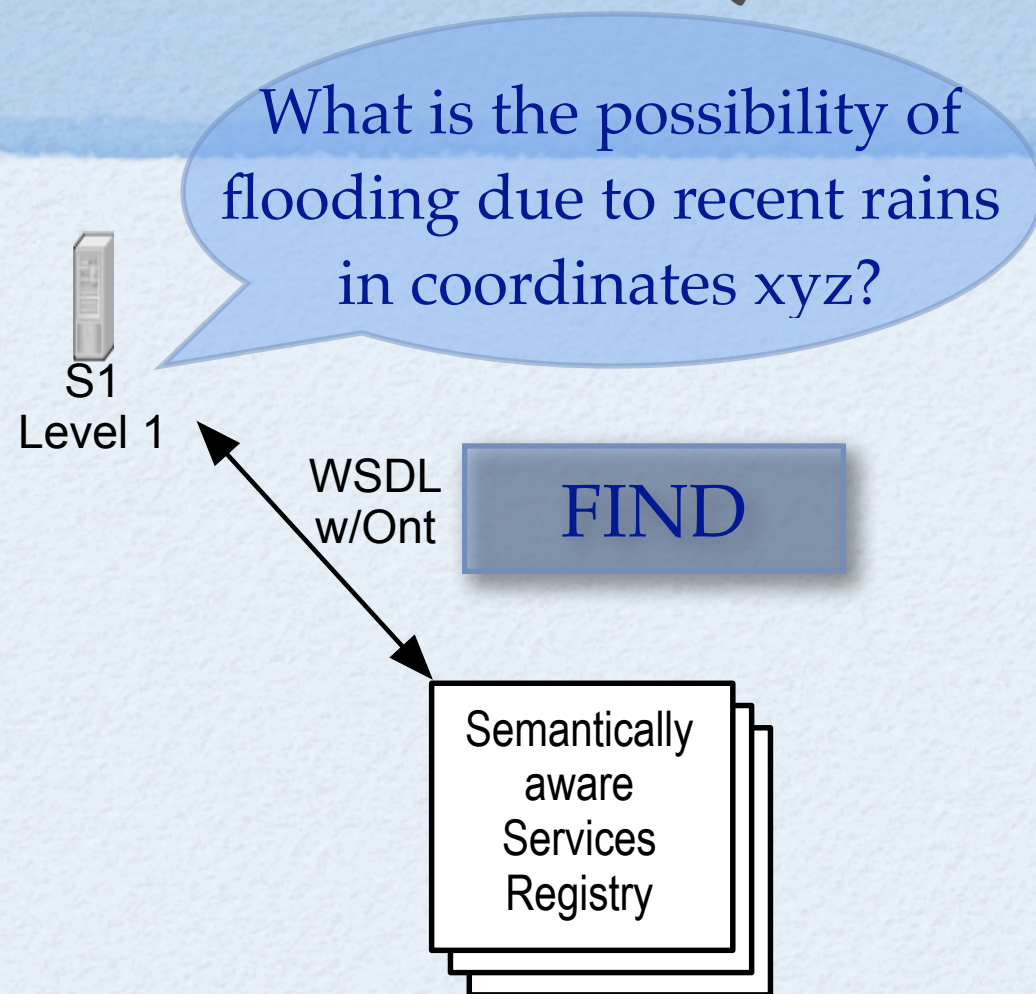
DISCOVERY WITH SEMANTICS

DISCOVERY WITH SEMANTICS



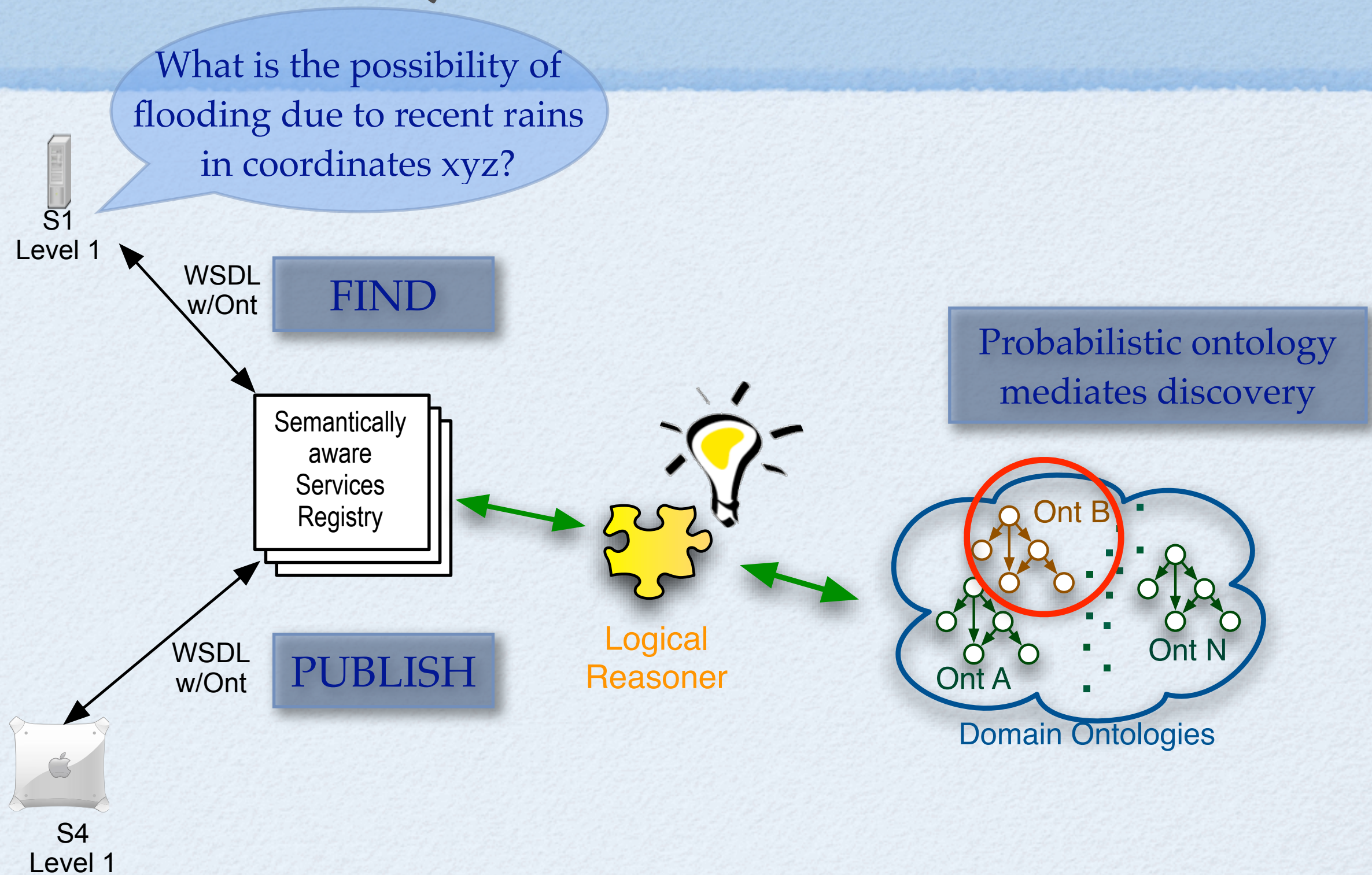
- *SOA Level 0*: Semantically unaware (legacy system)
- *SOA Level 1*: Understands and uses Semantics

DISCOVERY WITH SEMANTICS



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DISCOVERY WITH SEMANTICS



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DISCOVERY WITH SEMANTICS

What is the possibility of flooding due to recent rains in coordinates xyz?

S1
Level 1

WSDL
w/Ont

FIND

Semantically
aware
Services
Registry

WSDL
w/Ont

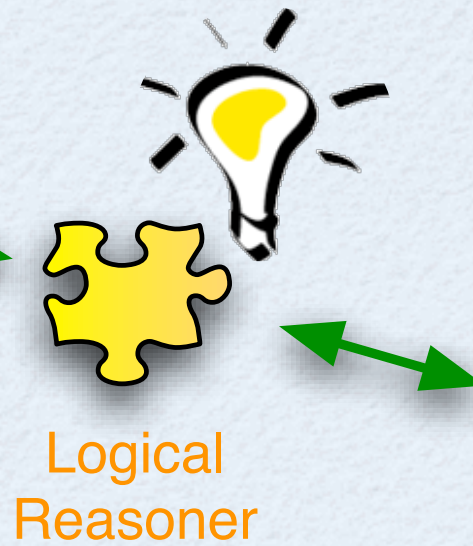
PUBLISH



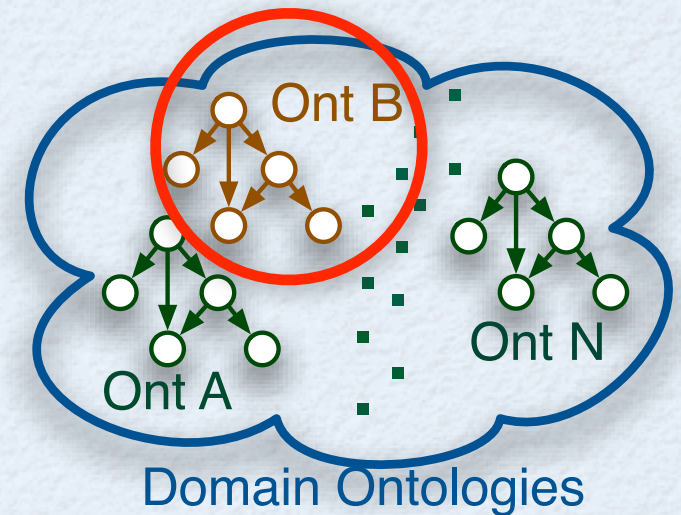
S4
Level 1

35% chances of flooding!

BIND

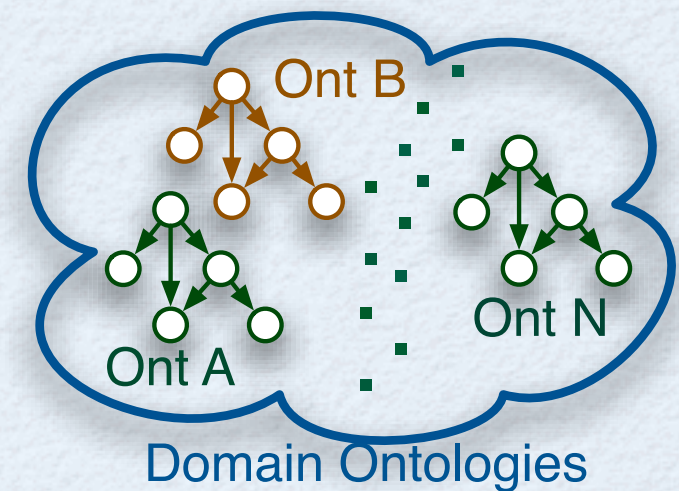


Probabilistic ontology
mediates discovery



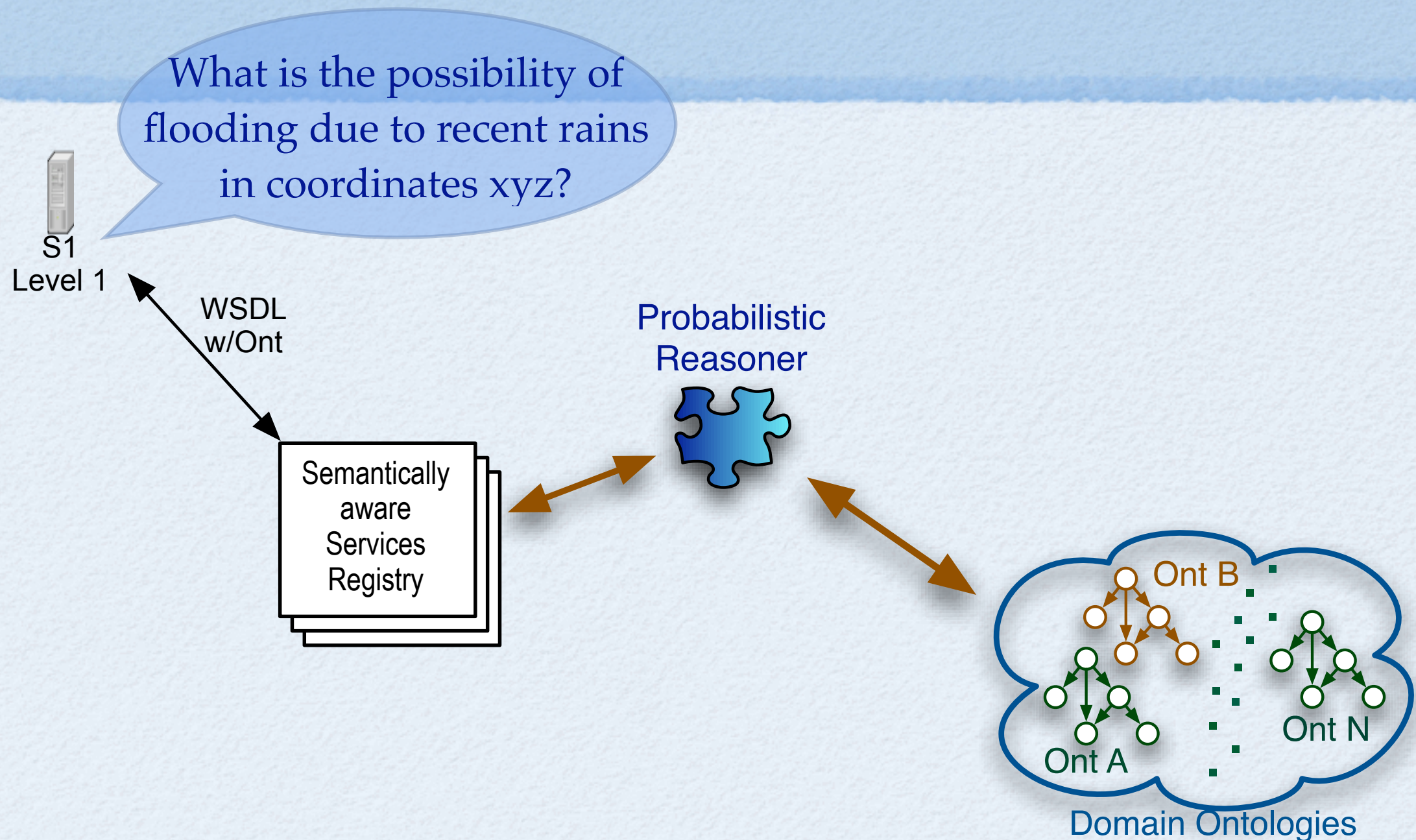
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PROBABILISTIC SEMANTIC MAPPING



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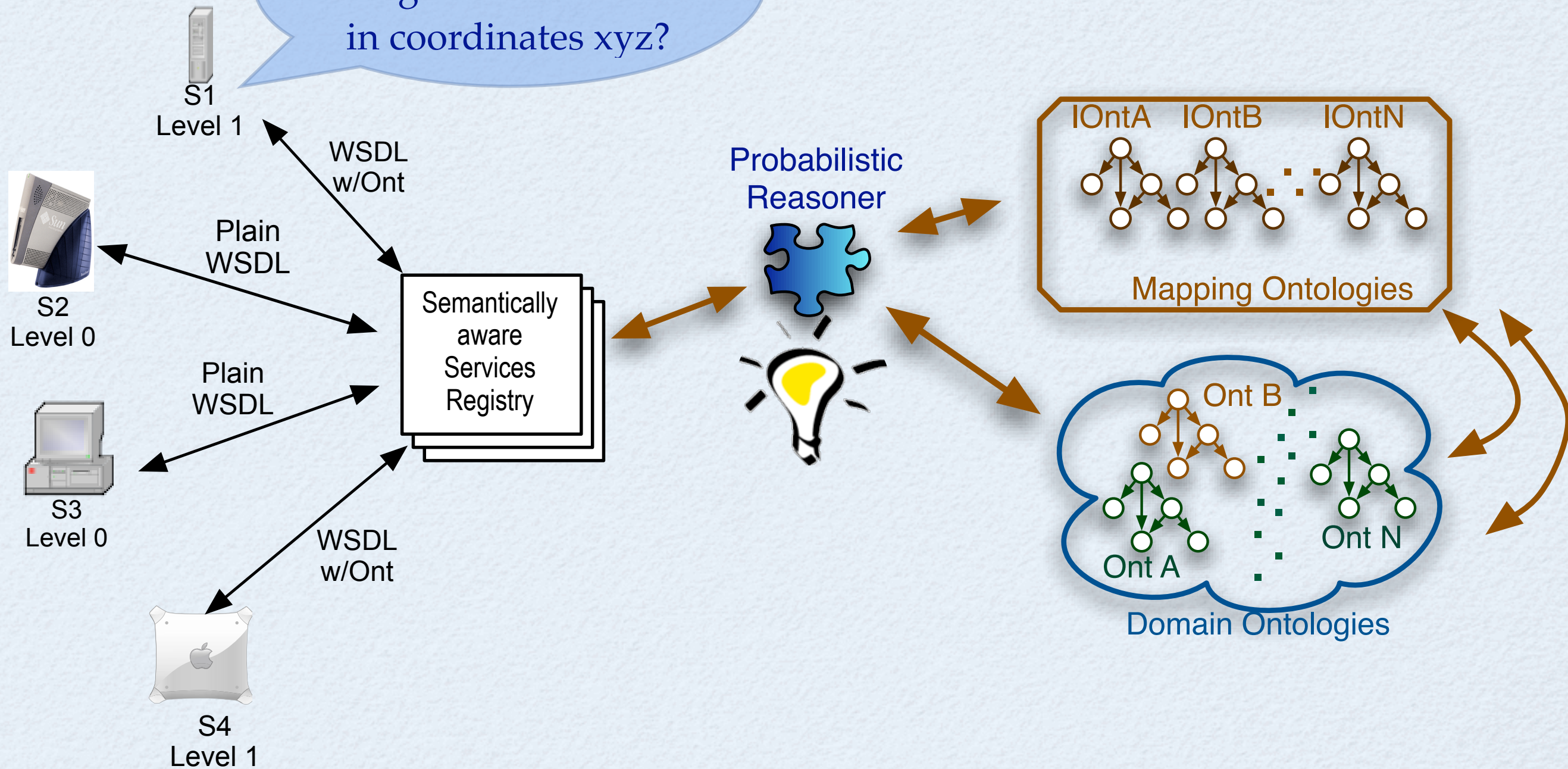
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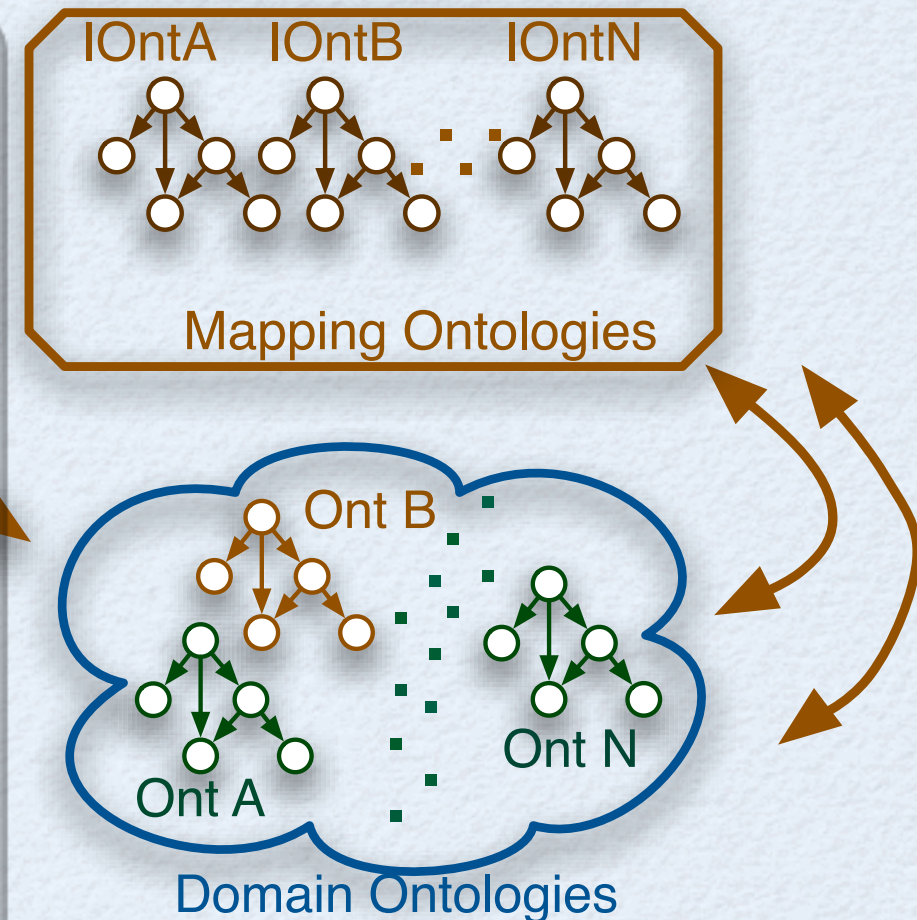


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PROBABILISTIC SEMANTIC MAPPING

What is the possibility of flooding due to recent rains in coordinates xyz?

- **A probabilistic ontology augments a standard ontology with a representation of uncertainty**
- **A mapping ontology represents mapping of terms between domain ontologies**



- **SOA Level 0**: Semantically unaware (legacy system)
- **SOA Level 1**: Understands and uses Semantics

CORE IDEAS

- ★ Probabilistic ontologies, as a principled representation of uncertainty, can extend the reach of Service Oriented Architectures.
- ★ Much can be achieved by combining both complete and incomplete knowledge to optimize the way resources are exchanged.

THANKS

BACKUP SLIDES

A PHILOSOPHICAL NOTE...

Two competing views:

A PHILOSOPHICAL NOTE...

Two competing views:

Probability as a natural phenomenon

VS.

Probability as an epistemic phenomenon

THE "PHLOGINSTON ONTOLOGY"

THE "PHLOGISTON ONTOLOGY"

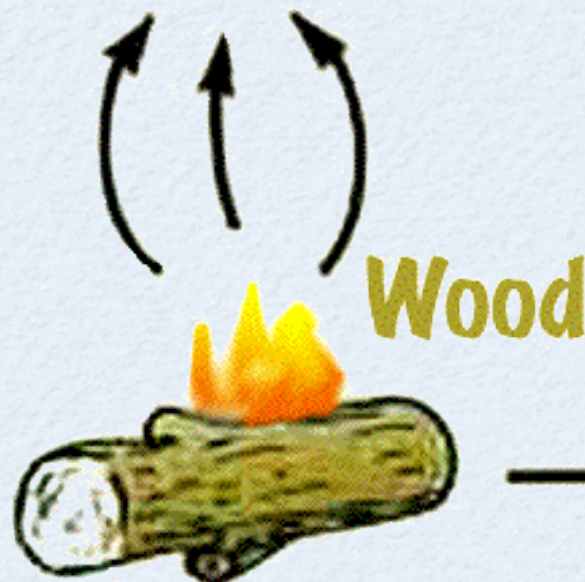
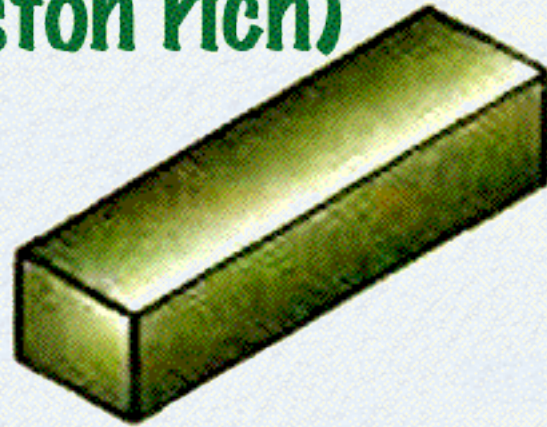
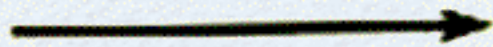


Earth (phlogiston poor)

Metal (phlogiston rich)



Fire (phlogiston)



Phlogiston Rich



Phlogiston in Air

+

Ashes



No Phlogiston



● OWLClasses ■ Properties ■ Forms ◆ Individuals ● Metadata

SUBCLASS RELATIONSHIP

For Project: ● Starship

- Asserted Hierarchy
- owl:Thing
 - ▼ ● pr-owl:ArgRelationship
 - pr-owl:SimpleArgRelationship
 - pr-owl:BuiltInRV
 - pr-owl:CondRelationship
 - ▼ ● pr-owl:Entity
 - pr-owl:BooleanRVStates
 - pr-owl:CategoricalRVStates
 - pr-owl:MetaEntity
 - ▼ ● pr-owl:ObjectEntity
 - Zone
 - TimeStep
 - Starship
 - SensorReport
 - ▼ ● pr-owl:MFragment
 - pr-owl:Domain_MFragment
 - pr-owl:Finding_MFragment
 - pr-owl:MTheory
 - ▼ ● pr-owl:Node
 - pr-owl:Context
 - ▼ ● pr-owl:Input
 - pr-owl:Finding_input
 - pr-owl:Generative_input
 - ▼ ● pr-owl:Resident
 - ▼ ● pr-owl:Domain_Res
 - ZoneMD
 - ZoneEShips
 - ZoneFShips
 - ZoneNature
 - pr-owl:Finding_res
 - pr-owl:OVariable
 - pr-owl:ProbAssign
 - ▼ ● pr-owl:ProbDist
 - pr-owl:DeclarativeDist
 - pr-owl:PR-OWLTable
 - pr-owl:Skolem

CLASS EDITOR

For Class: ● Zone (instance of owl:Class)

Name

Zone

rdfs:comment

A zone can be either a deep space, a planetary system, or the boundary of a Black Hole.
 We assumed that a OwnStarship, when in operation (i.e. using its decision system), has 80% chance of being traveling in a Deep Space Zone, 15% in a Planetary System and 5% in the Boundaries of a Black Hole.
 In our model, Black Hole Boundaries are preferred places for ambushes from attacking starships with cloaking.

Annotations

Property	Value	Lang
rdfs:comment	A zone can be either a deep ...	

Asserted Inferred

Asserted Conditions

Condition	Source	Category
● pr-owl:ObjectEntity		NECESSARY & SUFFICIENT
▼ ∇ pr-owl:hasType pr-owl:MetaEntity	[from pr-owl:Entity]	NECESSARY
● ∃ pr-owl:hasType pr-owl:MetaEntity	[from pr-owl:Entity]	NECESSARY
● pr-owl:hasType = 1	[from pr-owl:Entity]	NECESSARY
● pr-owl:hasUID = 1	[from pr-owl:Entity]	NECESSARY
▼ ∇ pr-owl:isConditionantOf pr-owl:ProbAssign	[from pr-owl:Entity]	INHERITED
▼ ∇ pr-owl:isPossibleValueOf (pr-owl:Node ⊔ pr-owl:BuiltInRV)		INHERITED
▼ ∇ pr-owl:subOVar pr-owl:OVariable	[from pr-owl:ObjectEntity]	INHERITED

Properties

- ▼ ■ pr-owl:hasType (single pr-owl:MetaEntity)
 - 1 [from pr-owl:Entity]
 - ▼ ● pr-owl:MetaEntity [from pr-owl:Entity]
 - pr-owl:MetaEntity [from pr-owl:Entity]
 - ▼ ■ pr-owl:hasUID (single xsd:string)
 - 1 [from pr-owl:Entity]
 - ▼ ■ pr-owl:isPossibleValueOf (multiple pr-owl:Node ⊔ pr-owl:BuiltInRV)
 - ▼ ● pr-owl:Node ⊔ pr-owl:BuiltInRV [from pr-owl:Entity]
 - ▼ ■ pr-owl:isArgTermin (multiple pr-owl:ArgRelationship)
- Disjoints**
- TimeStep
 - Starship
 - SensorReport
- Necessary Conditions:**
- object entity

OWLClasses
 Properties
 Forms
 Individuals
 Metadata
 PR-OWL

R I C Ov Sk D

MFrag Builder SSBN Vizualizer

OBJECT ENTITY BROWSER

- For Project ● Starship
- pr-owl:ObjectEntity
 - Zone
 - TimeStep
 - Starship
 - SensorReport

RESIDENT NODE BROWSER

- For Project ● Starship
- pr-owl:Resident
 - StarshipClass
 - StarshipZone
 - Subject
 - ZoneEShips
 - ZoneFShips
 - ZoneMD

MFRAG BROWSER

- For Project ● Starship
- pr-owl:DomainMFrag
 - Zone
 - Transporter
 - DangerToSelf
 - DangerToOthers
 - SensorReport
 - SRData

Node Type

- Context
- Input
- Resident

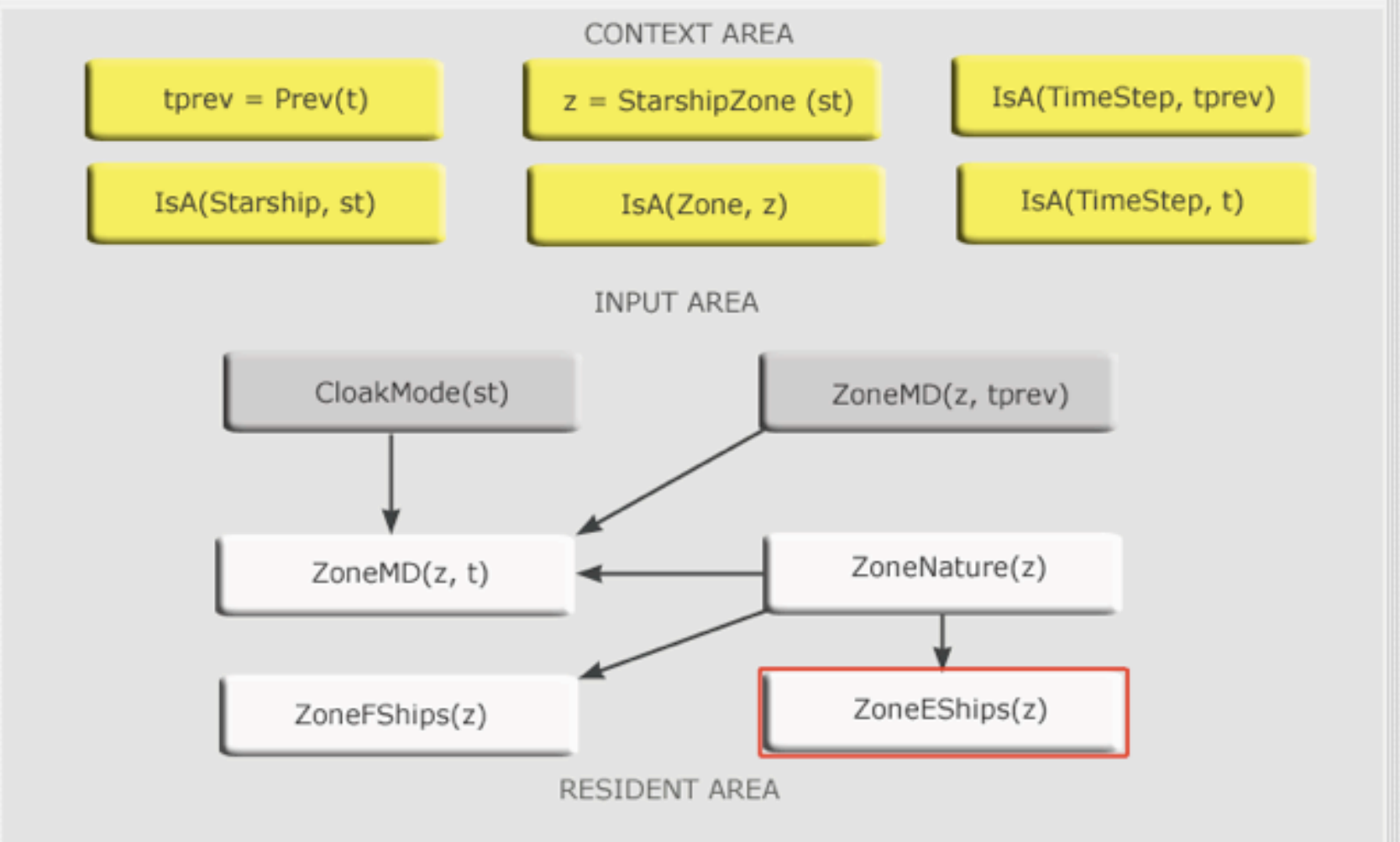
Link Arrow



Node Properties

- Ordinary Variable
- Skolem
- Prob Distr

pr-owl:Domain_MFrag
Zone



pr-owl:hasPossibleValues:
 ZES_MoreThan3
 ZES_3
 ZES_2
 ZES_1
 ZES_0

pr-owl:hasProbDist
 Z_ZoneEShips_decl_Quiddity
 Z_ZoneEShips_ddecl_Netica

pr-owl:hasArgument

WHY BAYES?

WHY BAYES?

★ Requirement: reason in the presence of uncertainty about...

- * Input data
- * Existence of relationships among entities
- * Strength of relationships
- * Constraints governing relationships

WHY BAYES?

★ Requirement: reason in the presence of uncertainty about...

- * Input data
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- * Strength of relationships
- * Constraints governing relationships

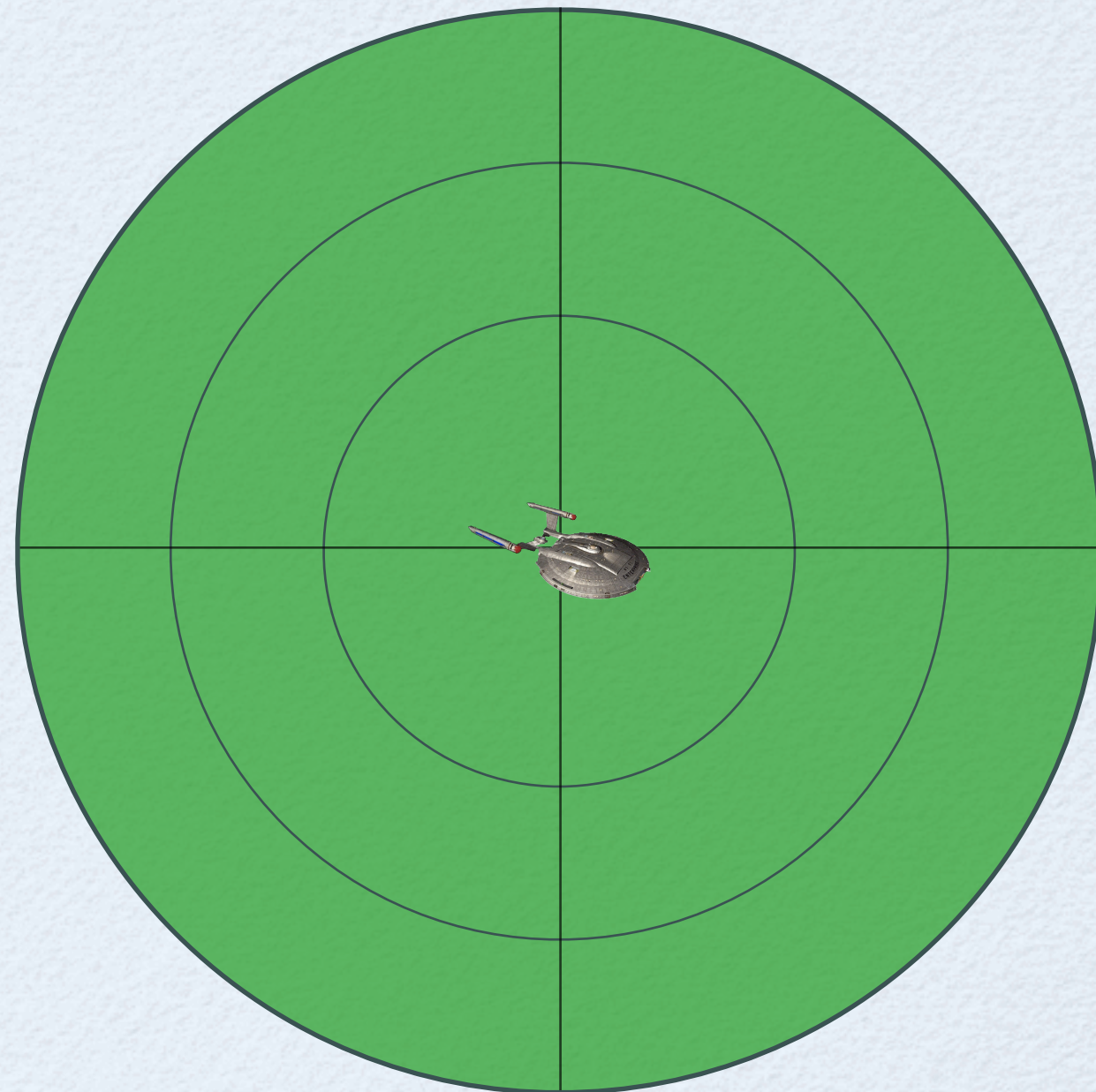
★ Solution: Bayesian inference

- * Combine expert knowledge with statistical data
- * Represent cause and effect relationships
- * Learn from observations
- * Prevent over-fitting
- * Clear and understandable semantics
- * Logically coherent

WHY BNs ARE UNFIT FOR POS?

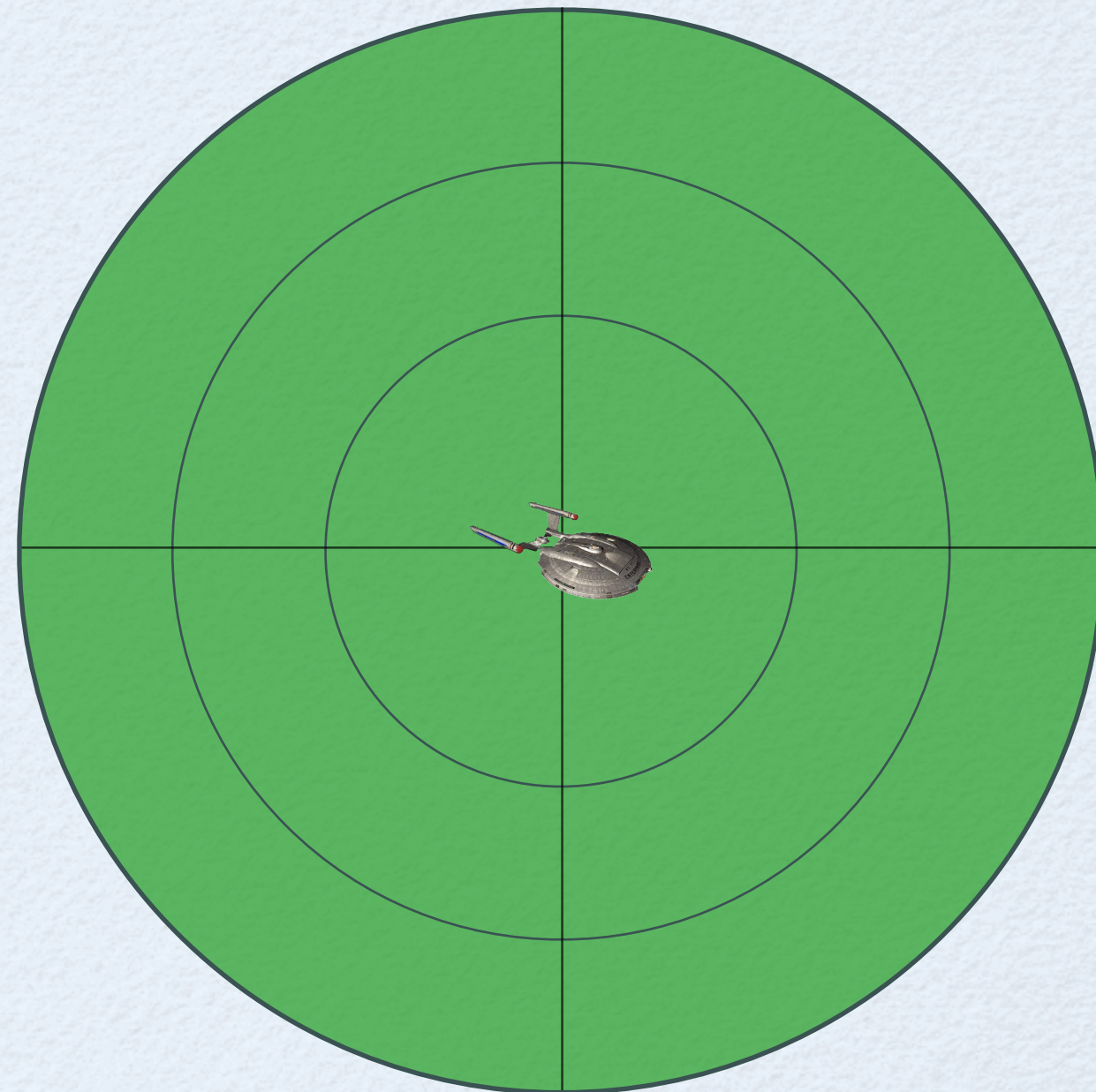
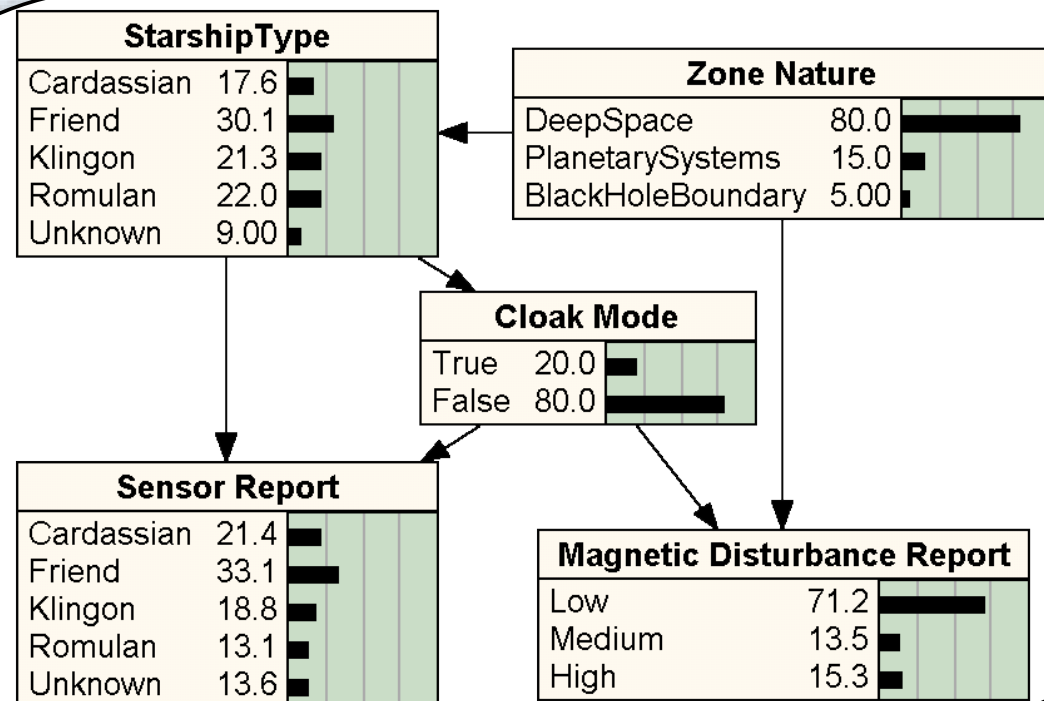
WHY BNS ARE UNFIT FOR POS?

BAYESIAN REASONING:
UPDATE PRIOR BELIEFS
AS EVIDENCE ACCRUES.
ALL NEW DATA CAN BE
CONSIDERED.



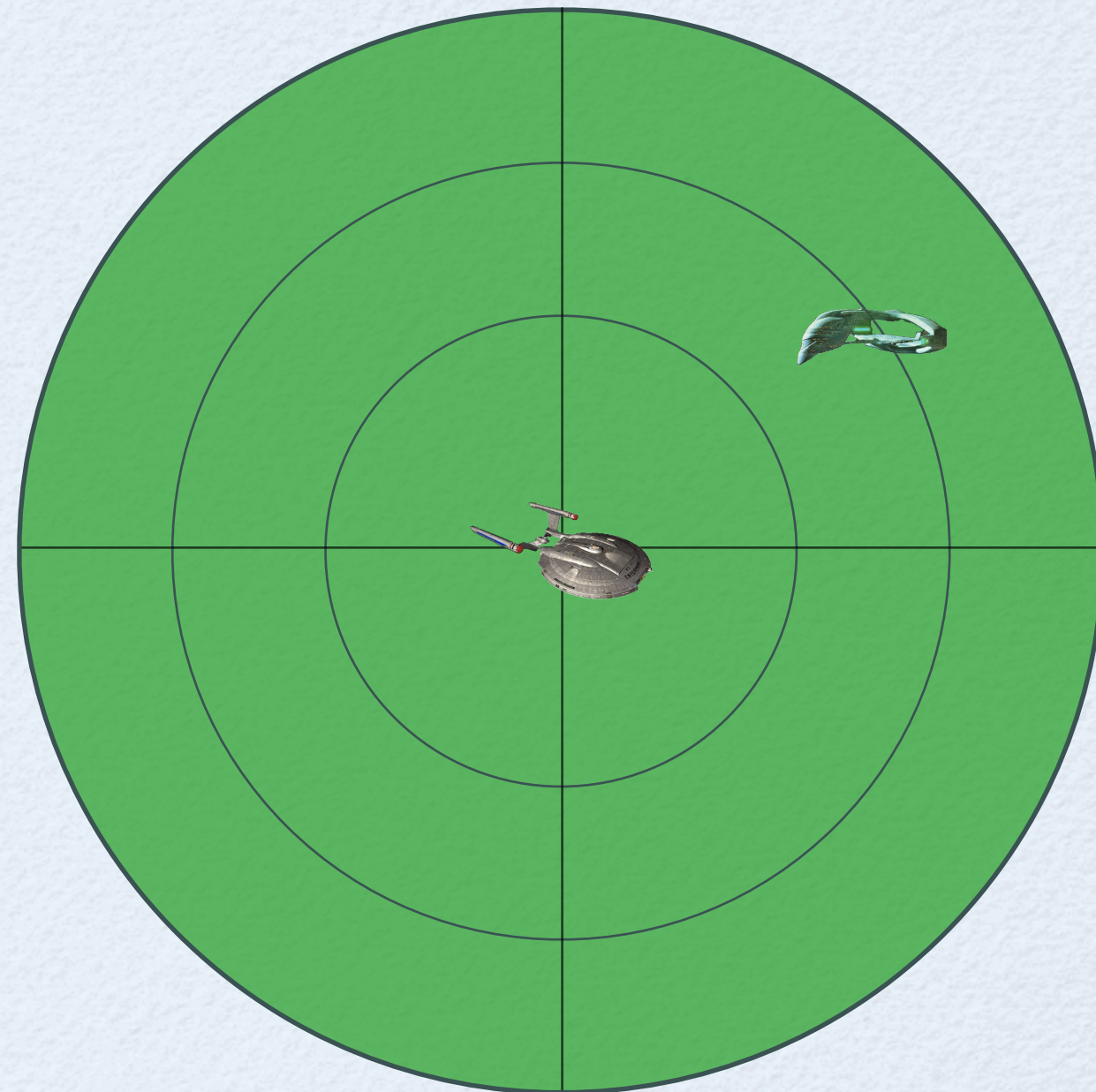
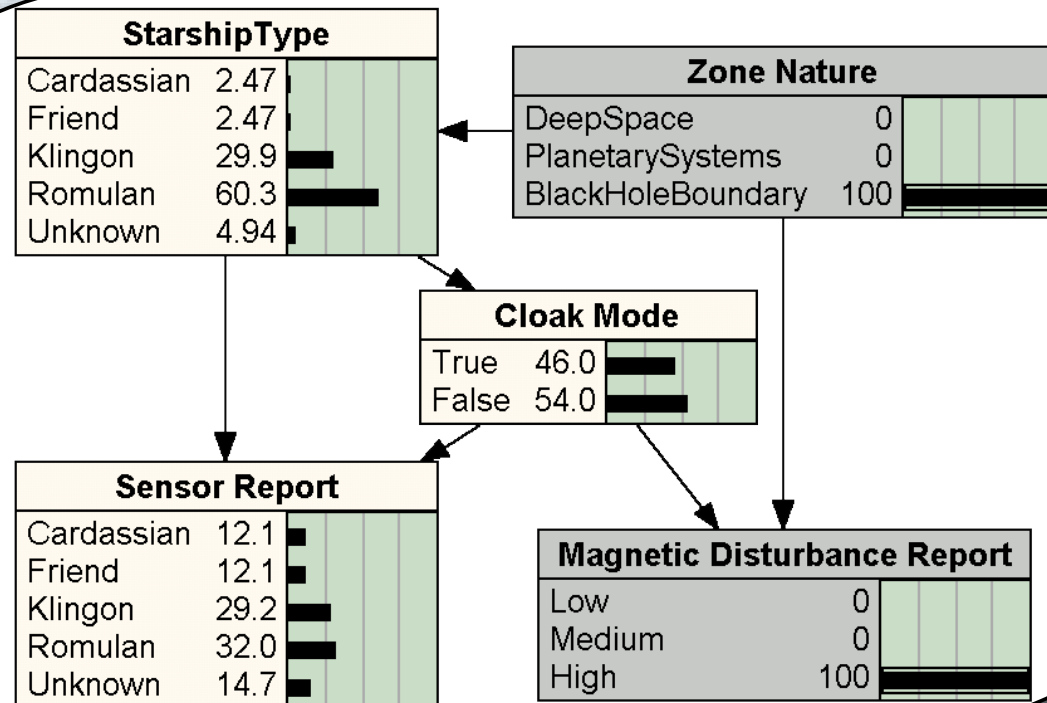
The Star Trek Problem: Discriminating Starships and making decisions with incomplete and uncertain knowledge

WHY BNs ARE UNFIT FOR POS?



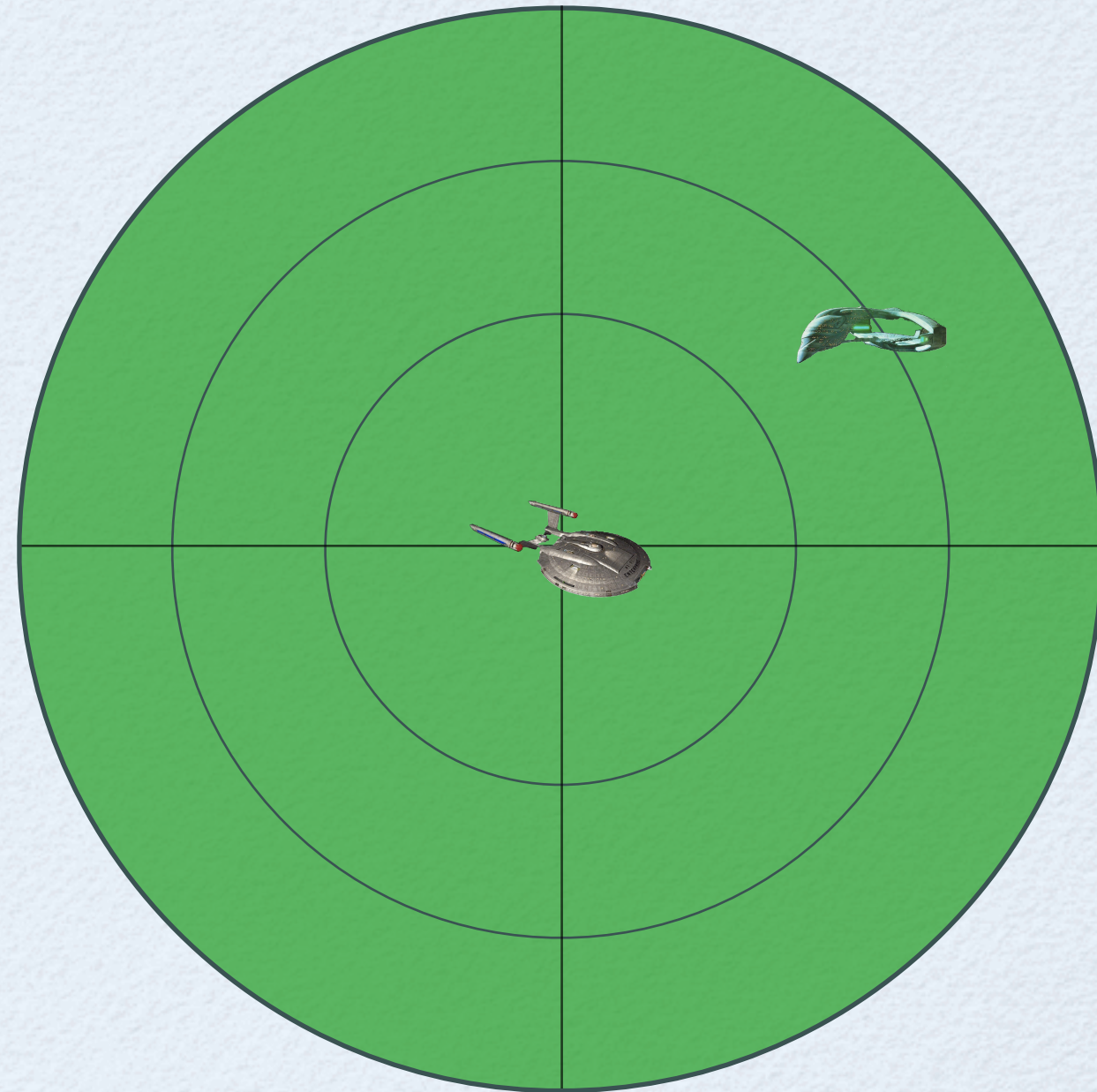
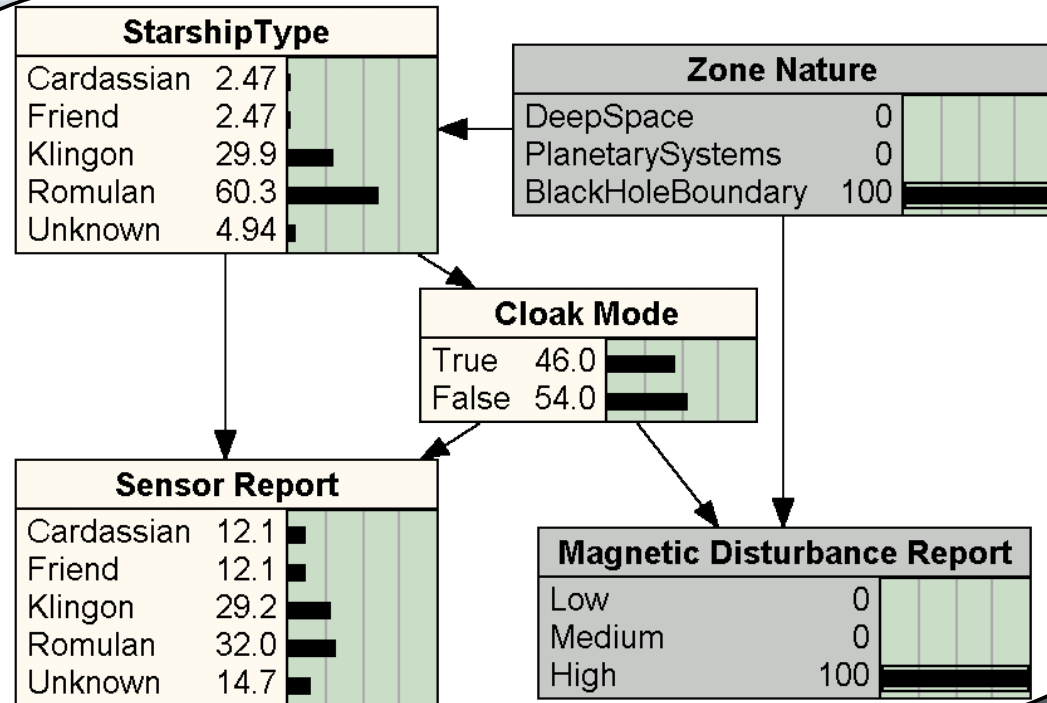
The Star Trek Problem: Discriminating Starships and making decisions with incomplete and uncertain knowledge

WHY BNs ARE UNFIT FOR POS?



The Star Trek Problem: Discriminating Starships and making decisions with incomplete and uncertain knowledge

WHY BNs ARE UNFIT FOR POS?



WHY BNs ARE UNFIT FOR POS?

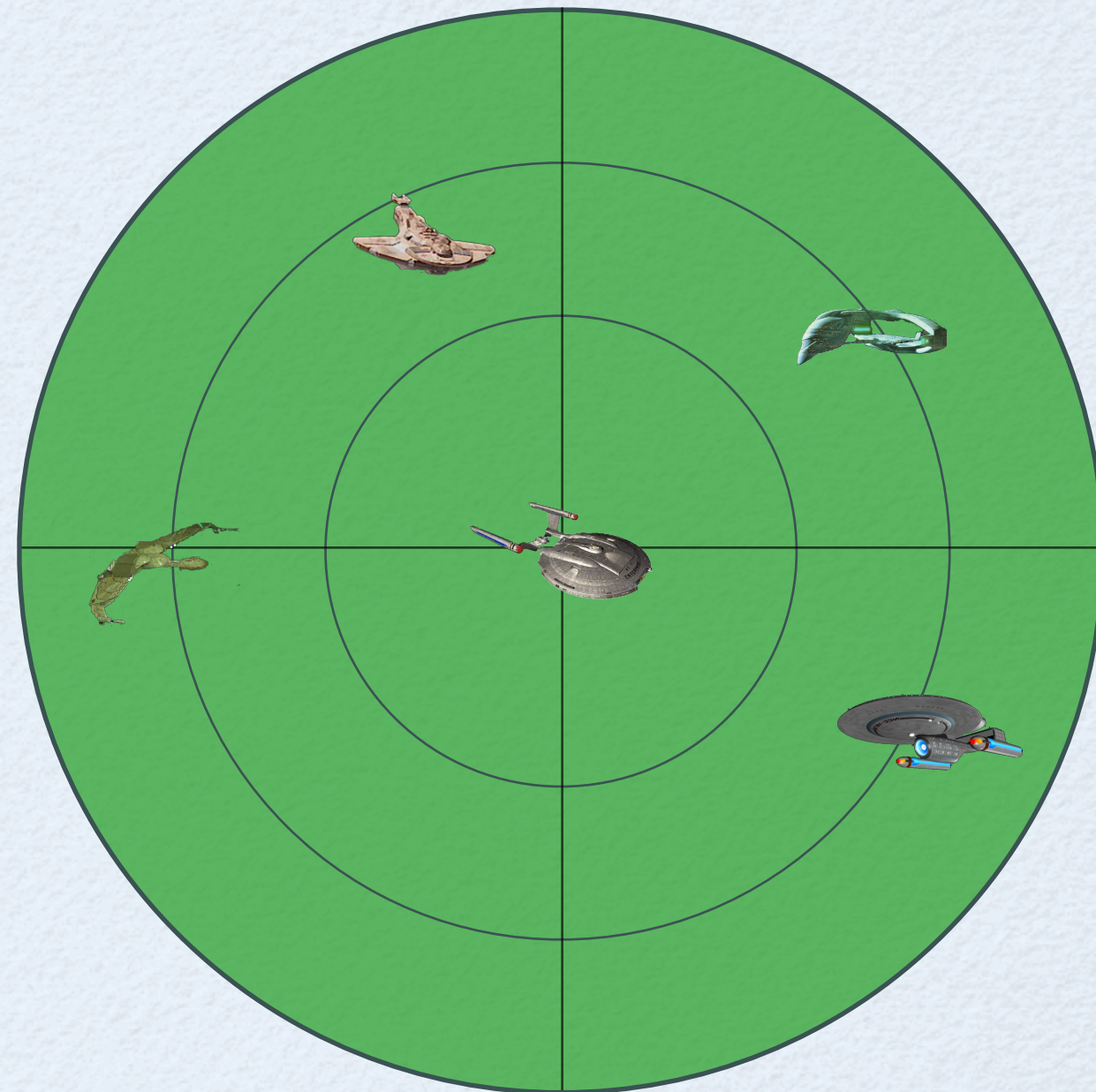
StarshipType	
Cardassian	2.47
Friend	2.47
Klingon	2.47
Romulan	2.47
Unknown	2.47

Sensor Report	
Cardassian	12.1
Friend	12.1
Klingon	29.2
Romulan	32.0
Unknown	14.7

Link Mode	
True	<input type="checkbox"/>
False	<input type="checkbox"/>

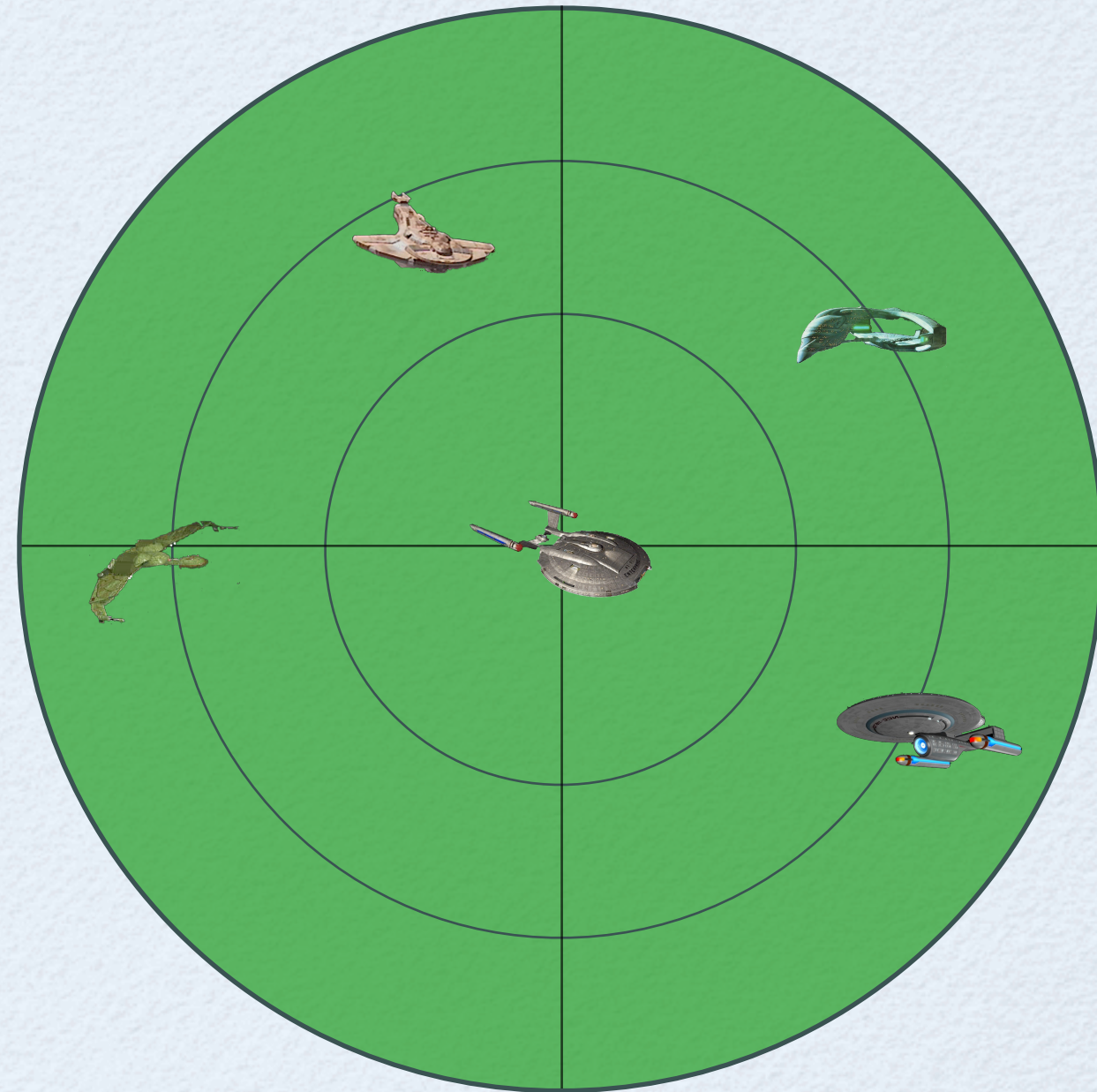
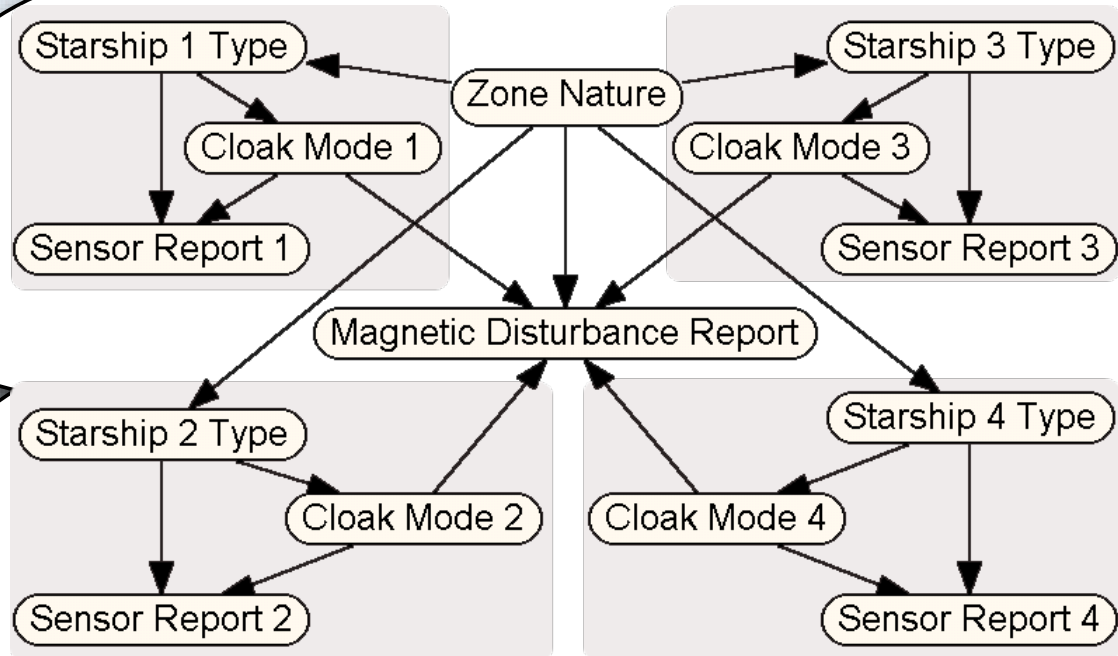
Magnetic Interference Report	
Low	0
High	100

Object Nature	
DeepSpace	0
PlanetarySystem	0
BlackHoleBoundary	100



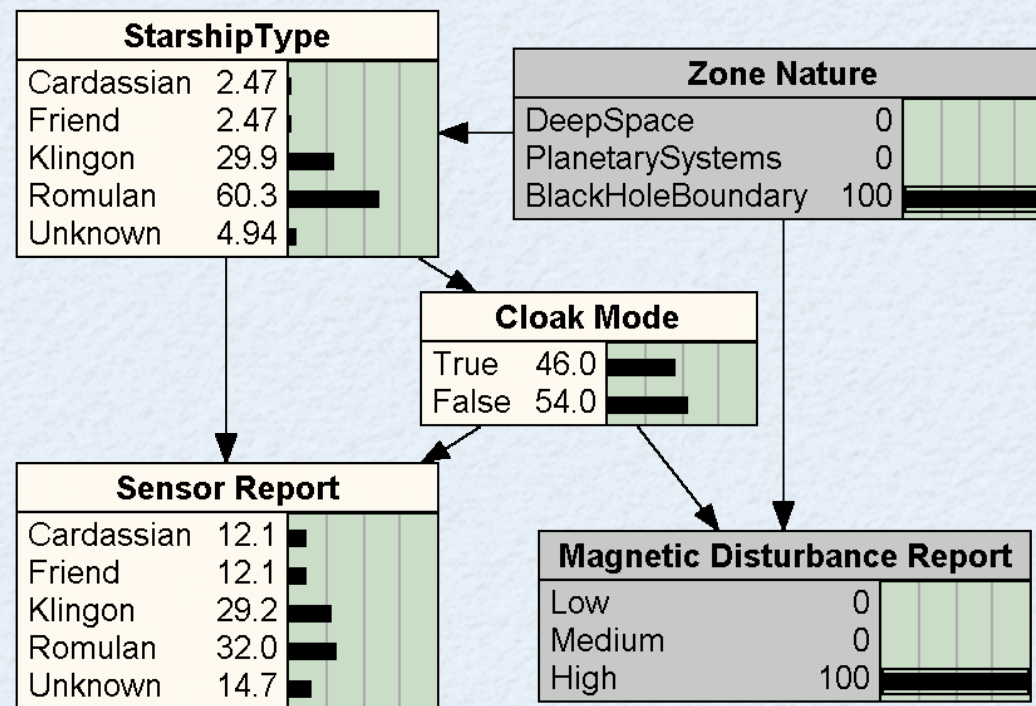
How about multiple starships showing up at the same time? One BN for each situation?

WHY BNs ARE UNFIT FOR POS?

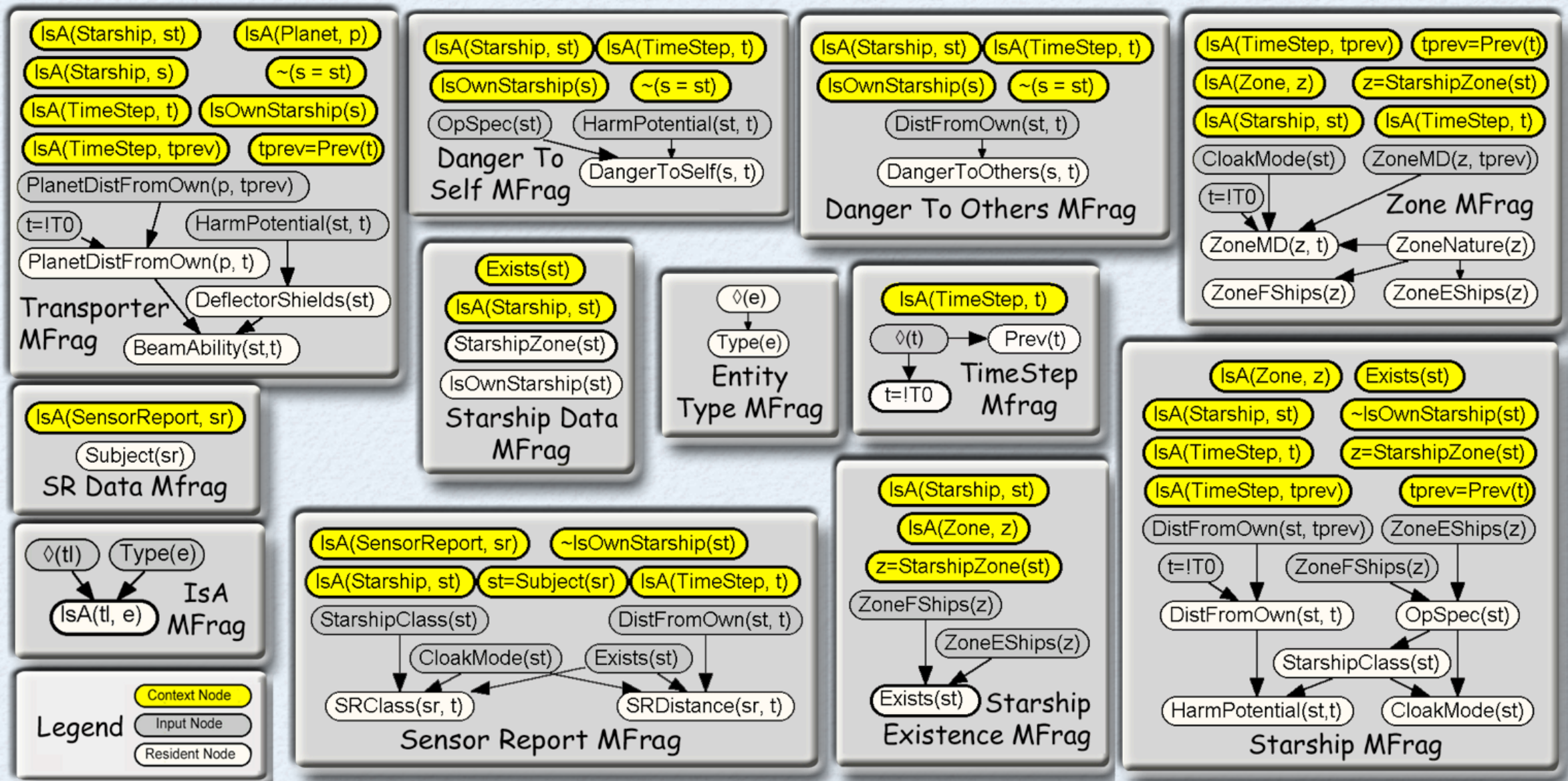


How about multiple starships showing up at the same time? One BN for each situation?

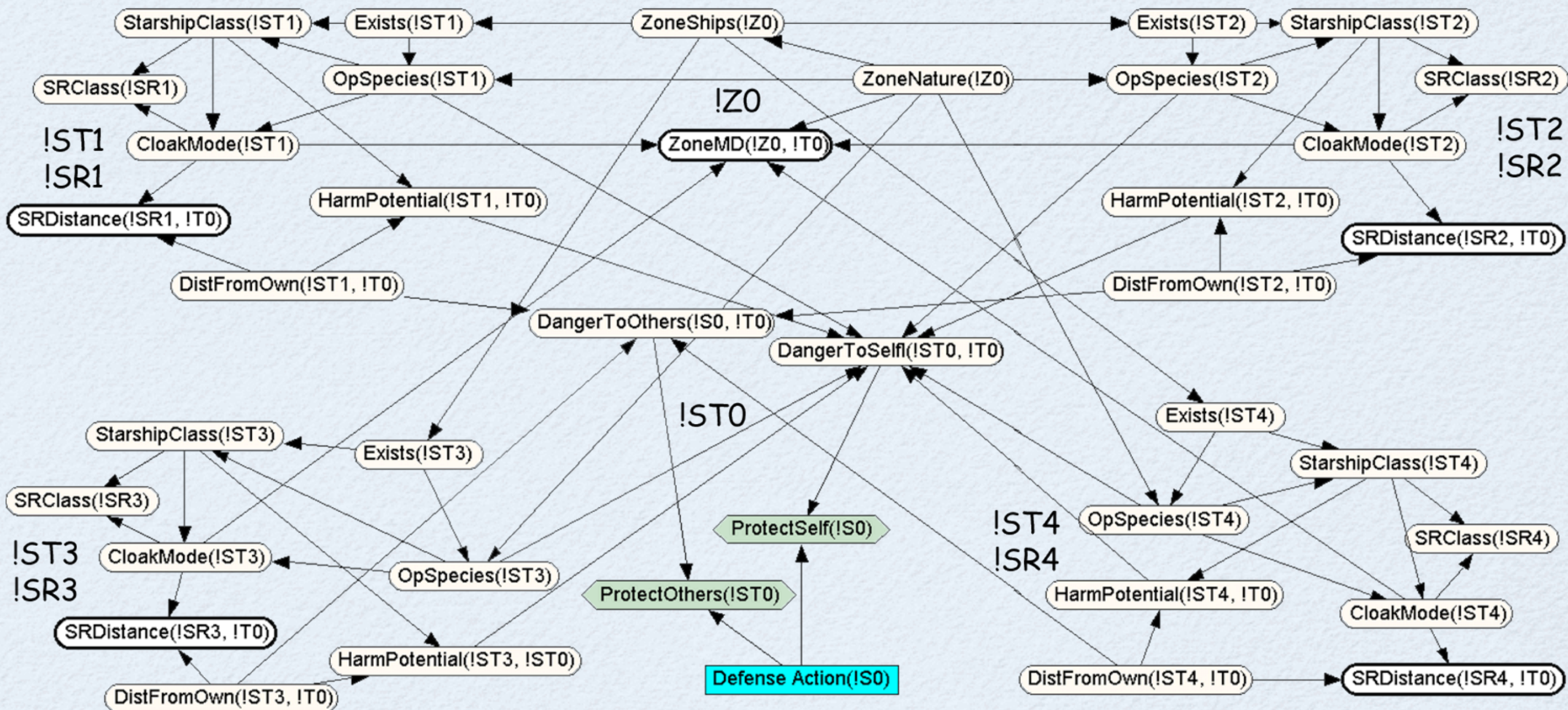
MEBN: FOL Expressiveness



MEBN: FOL Expressiveness



MEBN: FOL Expressiveness

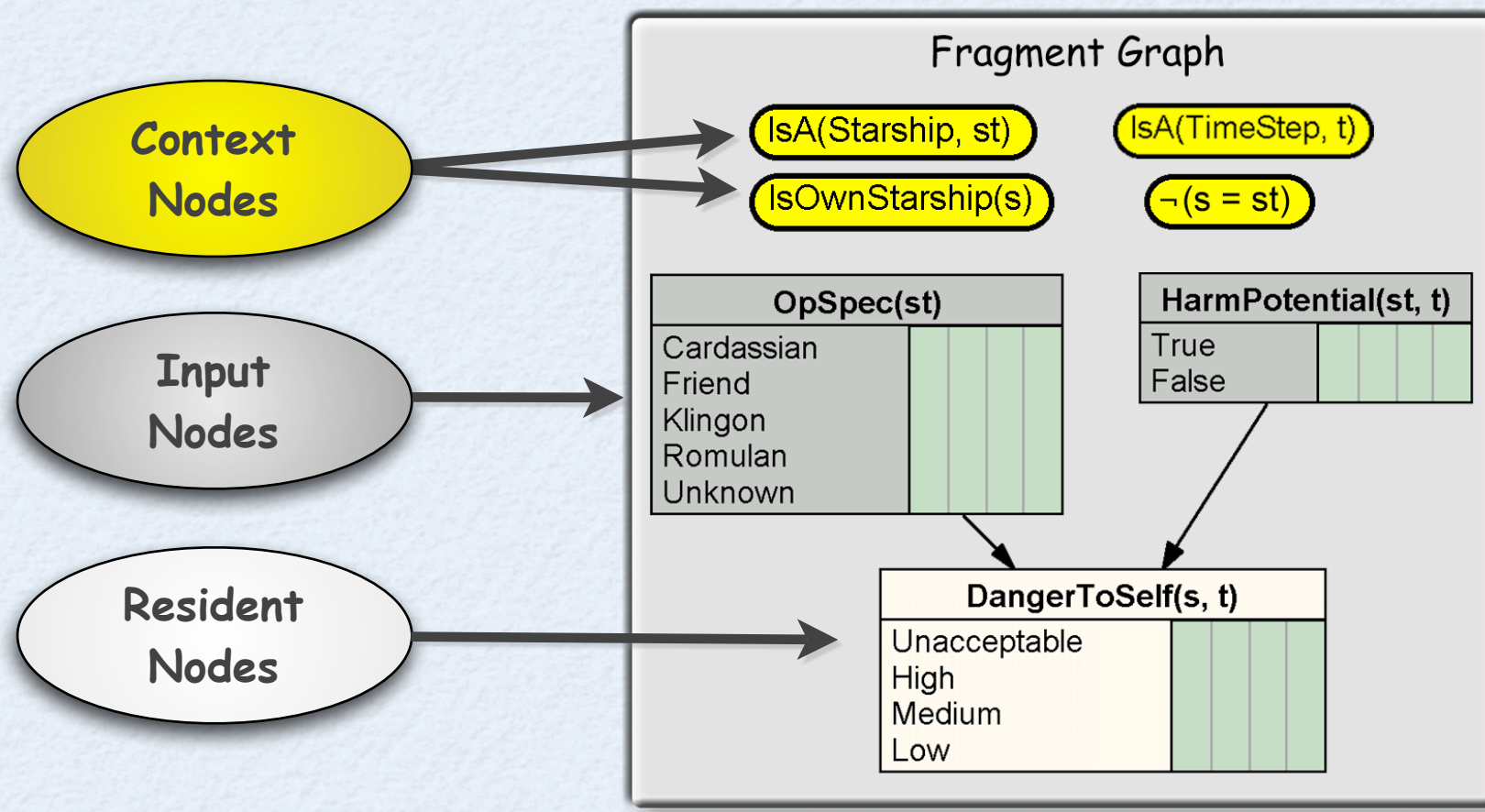


MEBN FRAGMENTS

Building blocks that collectively form a model
(MTheory)

MEBN FRAGMENTS

Building blocks that collectively form a model
(MTheory)



THE DANGER TO SELF MFRAG

IMPLEMENTATION APPROACH

IMPLEMENTATION APPROACH

★ Upper Ontology (e.g. OWL-S)

vs.

Semantic Extension (e.g. SWRL)

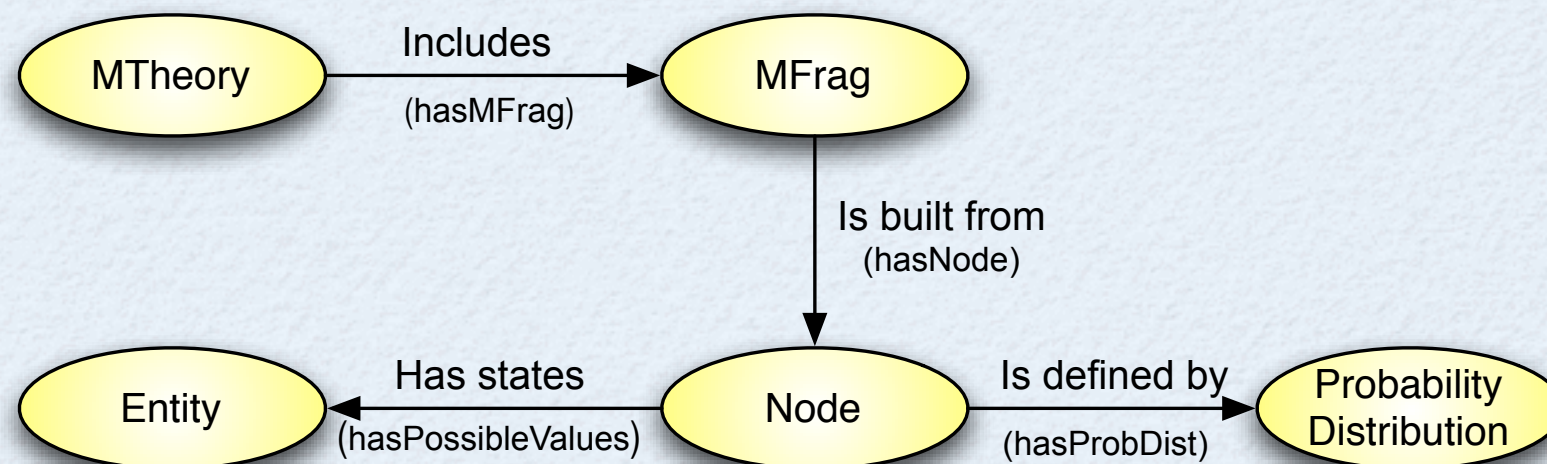
IMPLEMENTATION APPROACH

★ Upper Ontology (e.g. OWL-S)

vs.

Semantic Extension (e.g. SWRL)

★ Initial Approach: An upper ontology for probabilistic systems

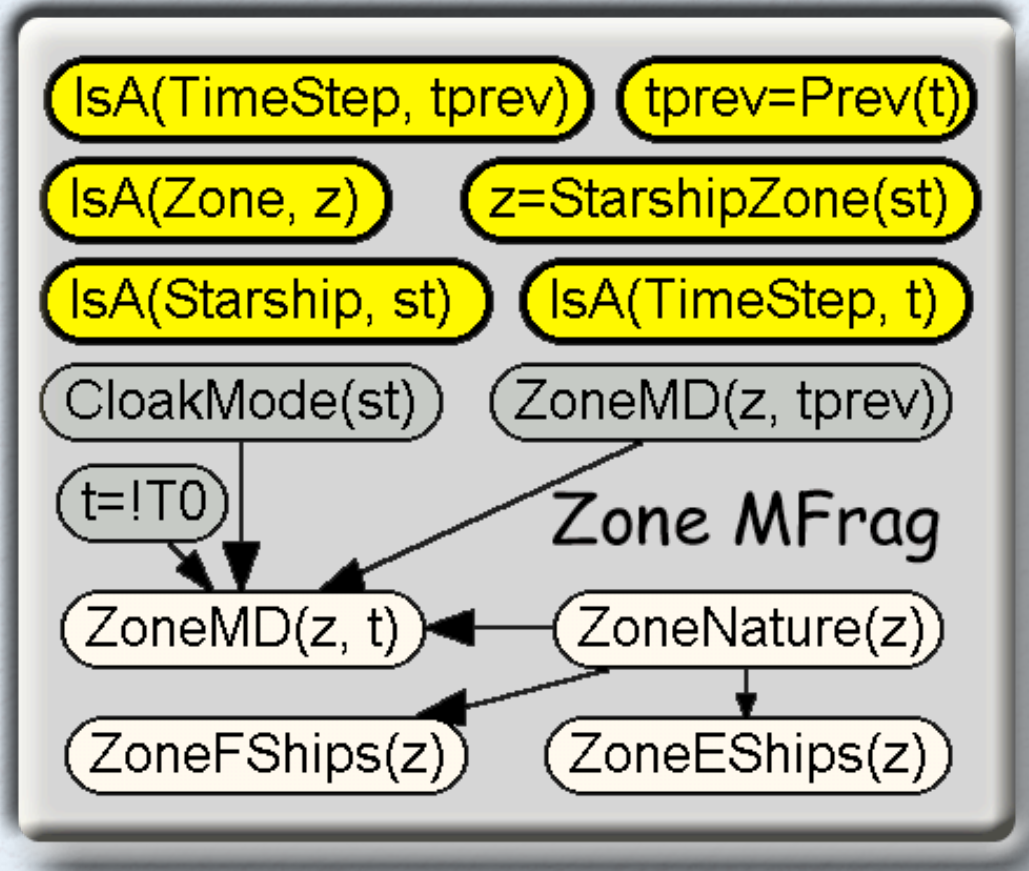


MEBN/PR-OWL

MEBN MFrag	PR-OWL Representation
<i>IsA(TimeStep, tprev)</i>	<none>
<i>IsA(Zone, z)</i>	
<i>IsA(Starship, st)</i>	
<i>IsA(TimeStep, t)</i>	
<i>tprev = Prev(t)</i>	Z_TprevPrevT_context
	Z_TprevPrevT_inner_prevT
<i>z = StarshipZone(st)</i>	Z_ZSZoneST_context
	Z_ZSZoneST_inner_SZoneST
<i>CloakMode(st)</i>	Z_CloakMode_input
<i>ZoneMD(z, tprev)</i>	Z_ZoneMD_input
<i>t = !T0</i>	Z_TequalT0_inpu
<i>ZoneMD(z, t)</i>	Z_ZoneMD
<i>ZoneNature(z)</i>	Z_ZoneNature
<i>ZoneFShips(z)</i>	Z_ZoneFShips
<i>ZoneEShips(z)</i>	Z_ZoneEShips

MEBN/PR-OWL

MEBN MFrag	PR-OWL Representation
<i>IsA(TimeStep, tprev)</i>	<none>
<i>IsA(Zone, z)</i>	
<i>IsA(Starship, st)</i>	
<i>IsA(TimeStep, t)</i>	
<i>tprev = Prev(t)</i>	Z_TprevPrevT_context
	Z_TprevPrevT_inner_prevT
<i>z = StarshipZone(st)</i>	Z_ZSZoneST_context
	Z_ZSZoneST_inner_SZoneST
<i>CloakMode(st)</i>	Z_CloakMode_input
<i>ZoneMD(z, tprev)</i>	Z_ZoneMD_input
<i>t = !T0</i>	Z_TequalT0_inpu
<i>ZoneMD(z, t)</i>	Z_ZoneMD
<i>ZoneNature(z)</i>	Z_ZoneNature
<i>ZoneFShips(z)</i>	Z_ZoneFShips
<i>ZoneEShips(z)</i>	Z_ZoneEShips



MEBN/PR-OWL

MEBN MFrag	PR-OWL Representation
$IsA(TimeStep, t_{prev})$	<none>
$IsA(Zone, z)$	
$IsA(Starship, st)$	
$IsA(TimeStep, t)$	
$t_{prev} = Prev(t)$	Z_TprevPrevT_context Z_TprevPrevT_inner_prevT
$z = StarshipZone(st)$	Z_ZSZoneST_context Z_ZSZoneST_inner_SZoneST
$CloakMode(st)$	Z_CloakMode_input
$ZoneMD(z, t_{prev})$	Z_ZoneMD_input
$t = !T0$	Z_TequalT0_inpu
$ZoneMD(z, t)$	Z_ZoneMD
$ZoneNature(z)$	Z_ZoneNature
$ZoneFShips(z)$	Z_ZoneFShips
$ZoneEShips(z)$	Z_ZoneEShips

beta (file:/Users/pc/Documents/Academia/Ontologies/Starship.pprj, OWL Files (.owl or .rdf))

protégé

OWLClasses Properties Forms Individuals Metadata

BROWSER INDIVIDUAL EDITOR

pr-owl:Domain_M... For Individual ◆ Zone_MFrag (instance of pr-owl:Domain_MFrag)

Name SameAs DifferentFrom

Zone_MFrag

rdfs:comment

Annotations

Property	Value	Lang
pr-owl:isMFragOf	Starship_MTheory	
pr-owl:hasNode	Z_TprevPrevT_context Z_ZSZoneST_context Z_TprevPrevT_inner_prevT Z_ZSZoneST_inner_SZoneST Z_TequalT0_input Z_ZoneMD_input Z_CloakMode_input Z_ZoneNature Z_ZoneEShips Z_ZoneFShips Z_ZoneMD	
pr-owl:hasSkolem		
pr-owl:hasInputNode	Z_TequalT0_input Z_ZoneMD_input Z_CloakMode_input	
pr-owl:hasContextNode	Z_st Z_tprev Z_z Z_t Z_TprevPrevT_context Z_ZSZoneST_context Z_TprevPrevT_inner_prevT Z_ZSZoneST_inner_SZoneST	
pr-owl:hasResidentNode	Z_ZoneNature Z_ZoneEShips Z_ZoneFShips Z_ZoneMD	

pr-owl:Entry

- pr-owl:BooleanRVStates (3)
- pr-owl:CategoricalRVStates (16)
- pr-owl:MetaEntity (7)
- pr-owl:ObjectEntity
- pr-owl:MFrag
 - pr-owl:Domain_MFrag (9)
 - pr-owl:Finding_MFrag
- pr-owl:MTheory (1)

Starship_MFrag
StarshipData_MFrag
StarshipExistence_MFrag
TimeStep_MFrag
Zone_MFrag

Zone MFrag

IsA(TimeStep, tprev) tprev=Prev(t)
IsA(Zone, z) z=StarshipZone(st)
IsA(Starship, st) IsA(TimeStep, t)
CloakMode(st) ZoneMD(z, tprev)
t=!T0
ZoneMD(z, t) ZoneNature(z)
ZoneFShips(z) ZoneEShips(z)

Domain_MFrag

1 pr-owl:isMFragOf
2 pr-owl:hasNode
3 pr-owl:hasOVariable
4 pr-owl:hasSkolem
5 pr-owl:hasInputNode
6 pr-owl:hasContextNode
7 pr-owl:hasResidentNode

THE ROAD AHEAD

THE ROAD AHEAD

★ Major Challenges:

- ★ Lack of full MEBN reasoners
- ★ Achieve a balance between complexity and interoperability

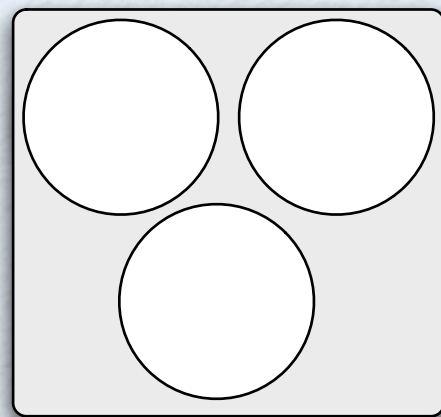
★ High Priority Objectives:

- ★ Develop a lite version of PR-OWL
- ★ W3C member submission for PR-OWL
- ★ Implementation of the Protégé Plugin

LOGICAL VS. PLAUSIBLE

LOGICAL VS. PLAUSIBLE

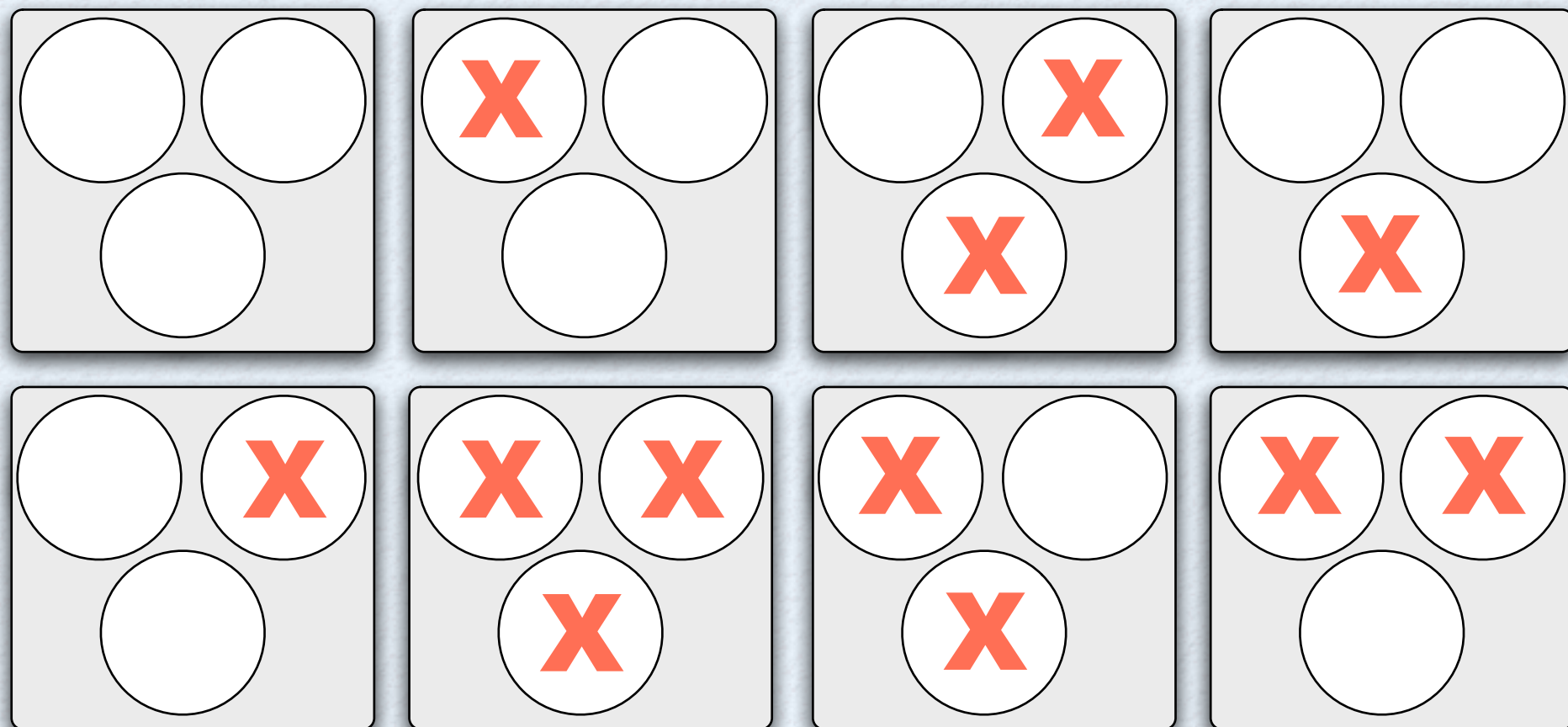
Three binary variables



LOGICAL VS. PLAUSIBLE

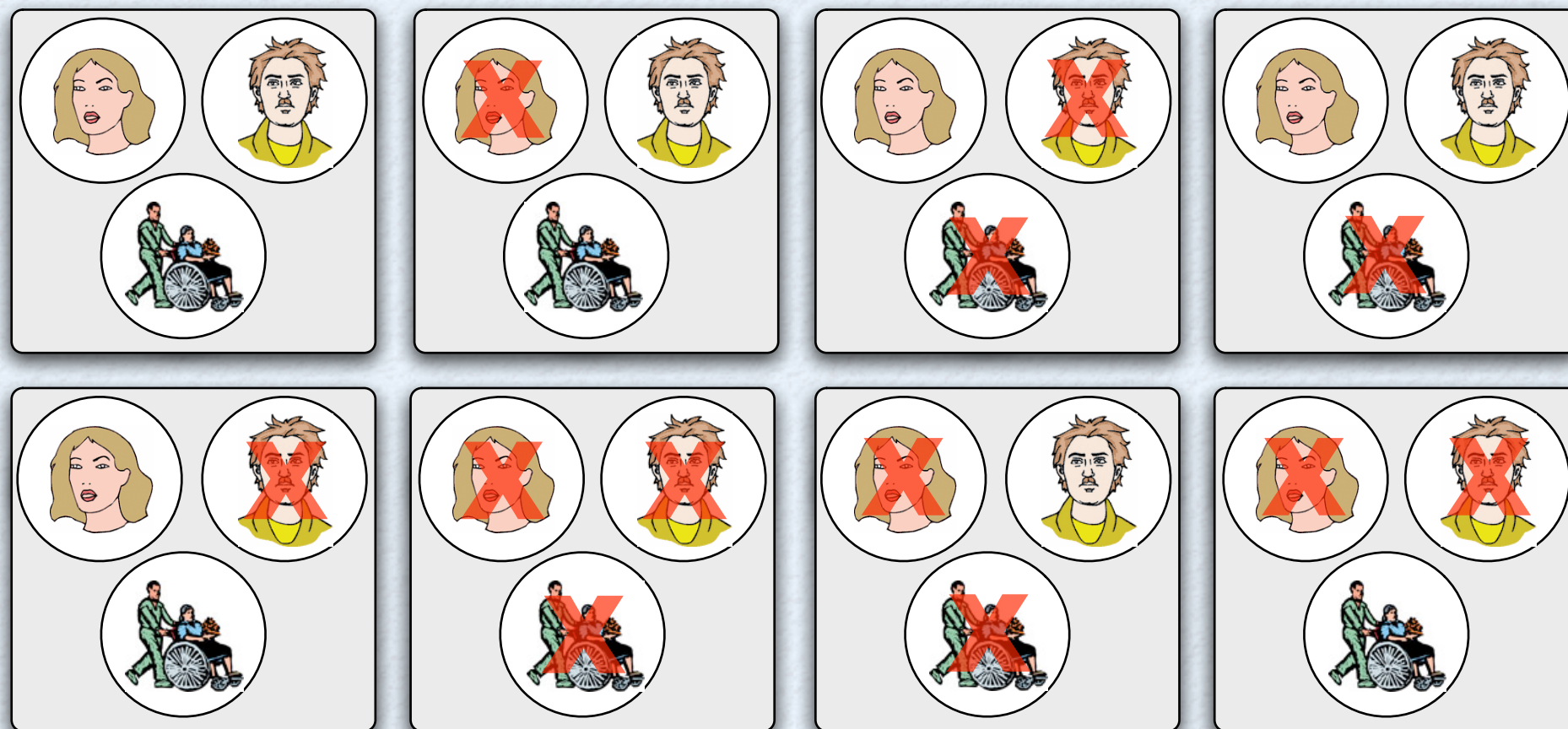
Three binary variables

$2^3 = 8$ possible combinations



LOGICAL VS. PLAUSIBLE

Does mom have transportation to the doctor tomorrow?

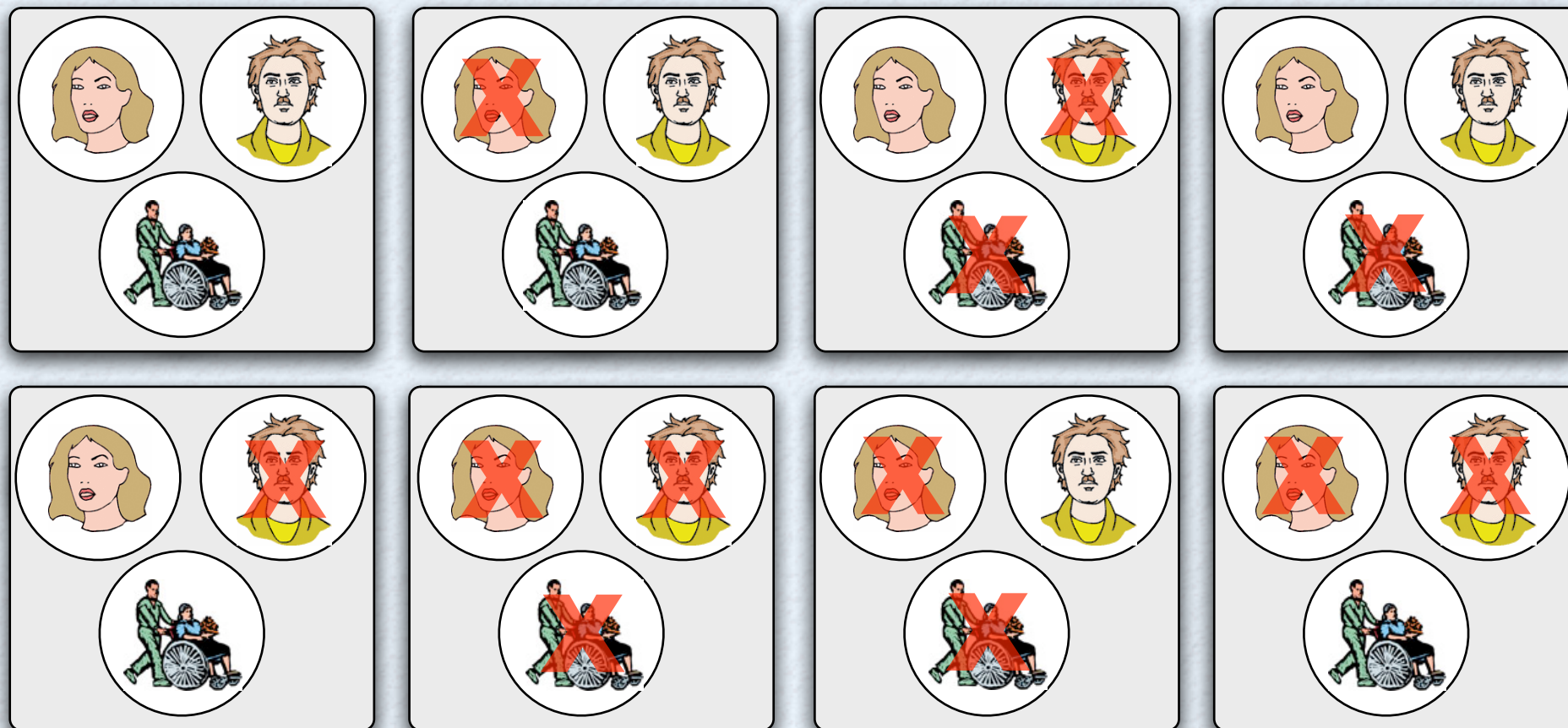


LOGICAL VS. PLAUSIBLE

Does mom have transportation to the doctor tomorrow?

1) Yes, if Lucy or Pete gives her a ride.

Otherwise, no.



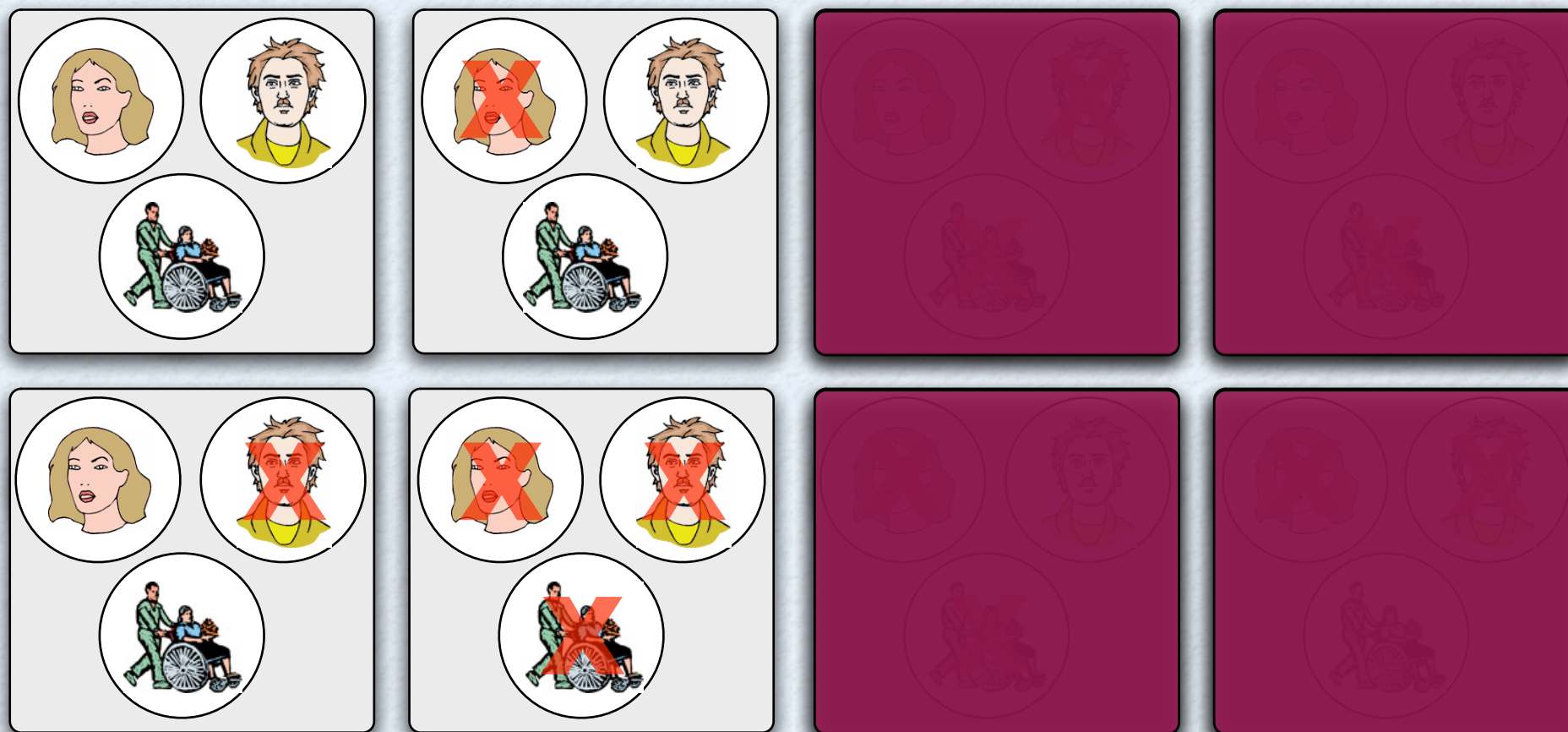
LOGICAL VS. PLAUSIBLE

Does mom have transportation to the doctor tomorrow?

1) Yes, if Lucy or Pete gives her a ride.

Otherwise, no.

	Logical	Plausible
Yes	?	75%
No	?	25%



LOGICAL VS. PLAUSIBLE

Does mom have transportation to the doctor tomorrow?

1) Yes, if Lucy or Pete gives her a ride.

Otherwise, no.

2) Pete can't make it tomorrow.

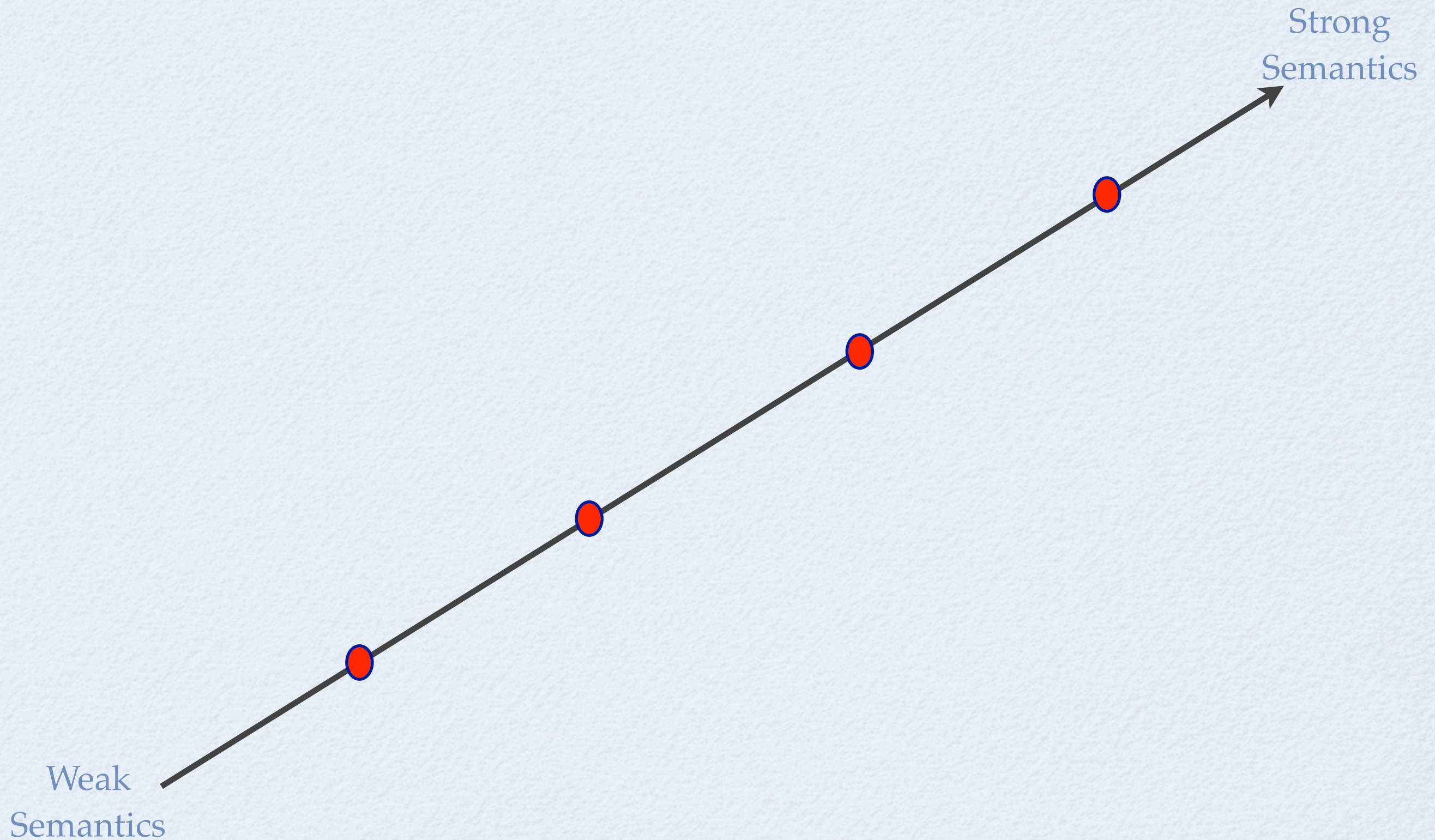
	Logical	Plausible
Yes	?	50%
No	?	50%



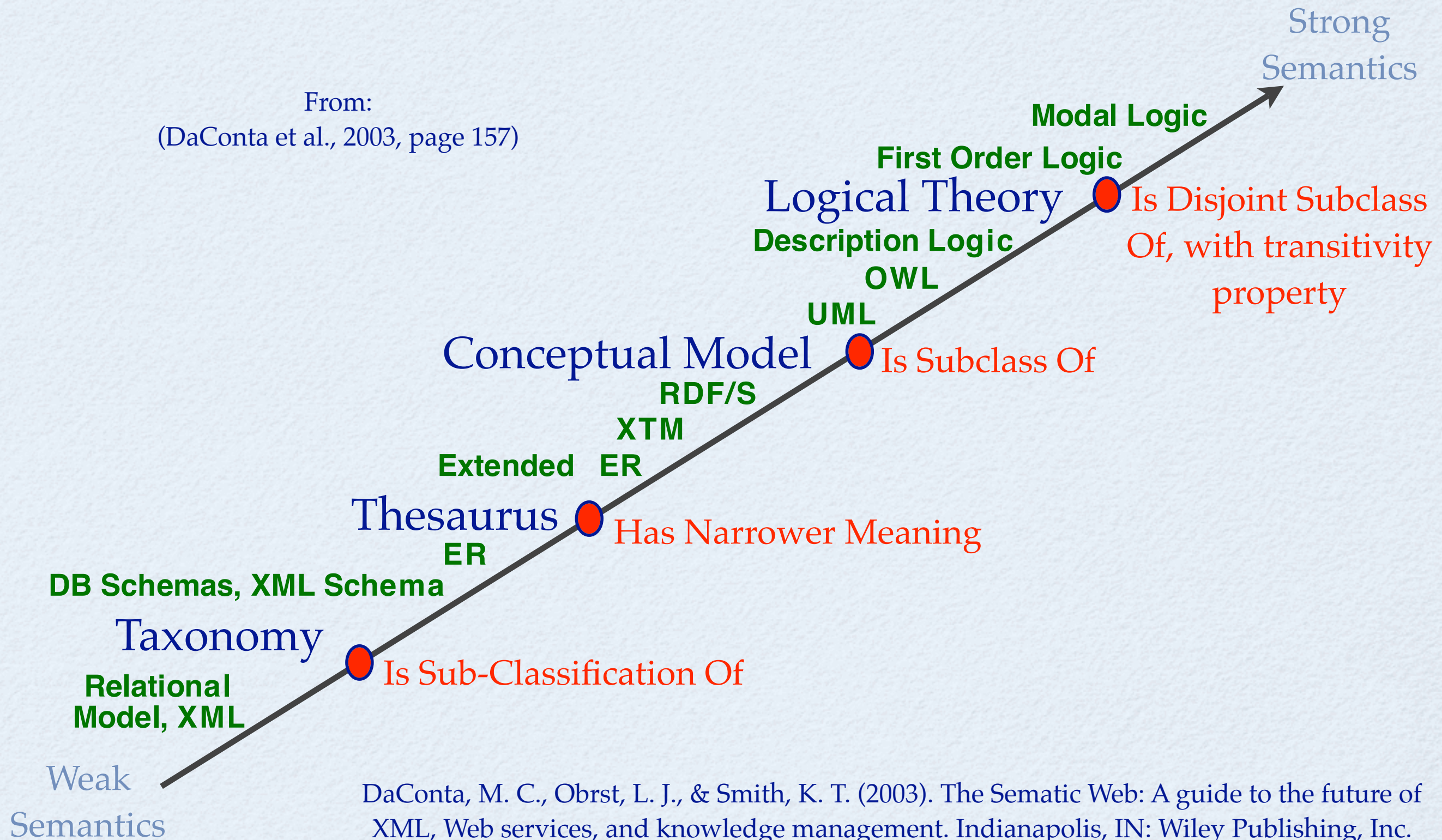
THE ONTOLOGY SPECTRUM

Weak
Semantics

THE ONTOLOGY SPECTRUM



THE ONTOLOGY SPECTRUM



SYSTEM INTERACTION

SYSTEM INTERACTION

SYSTEM A



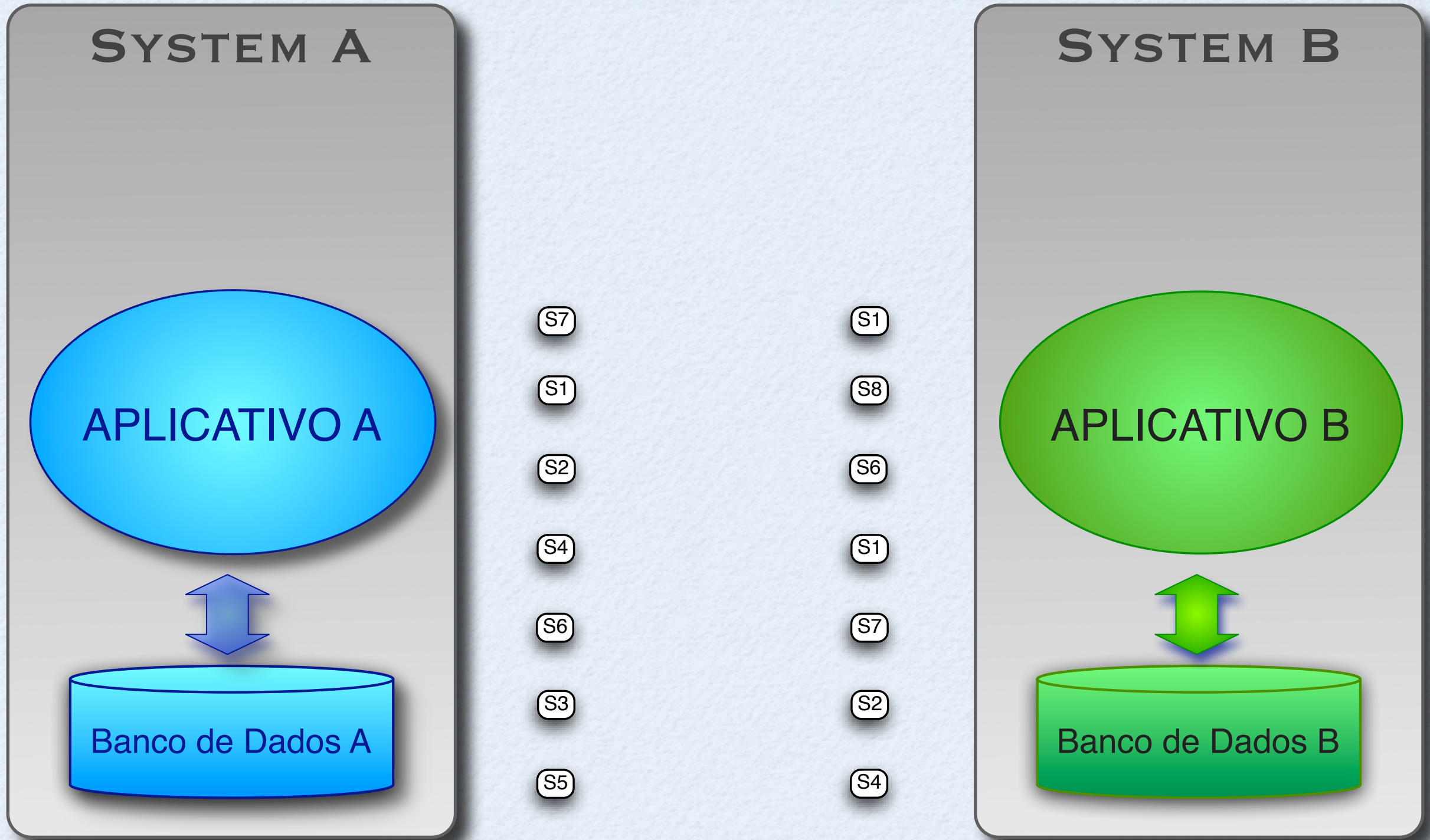
SYSTEM B



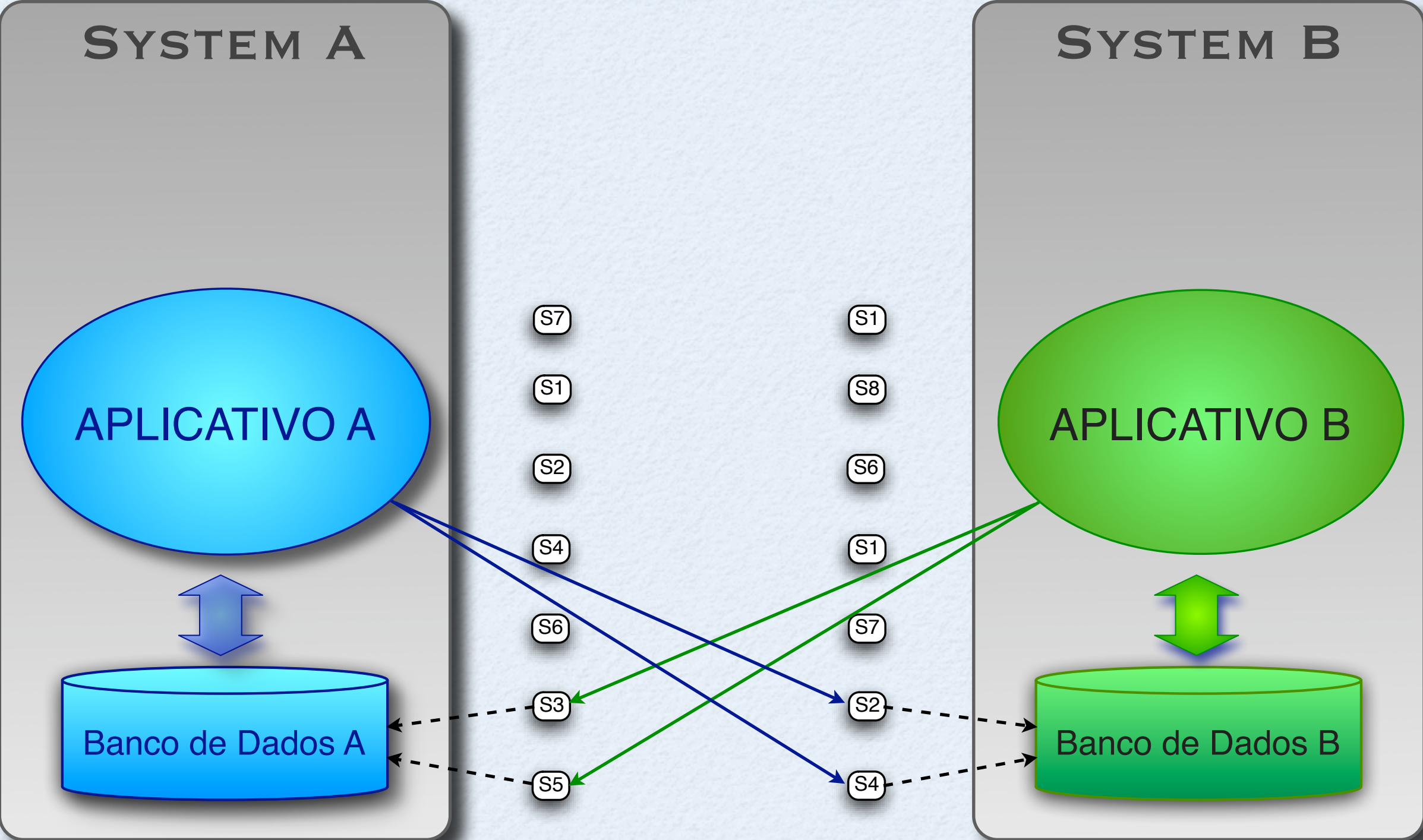
SYSTEM INTERACTION



SYSTEM INTERACTION

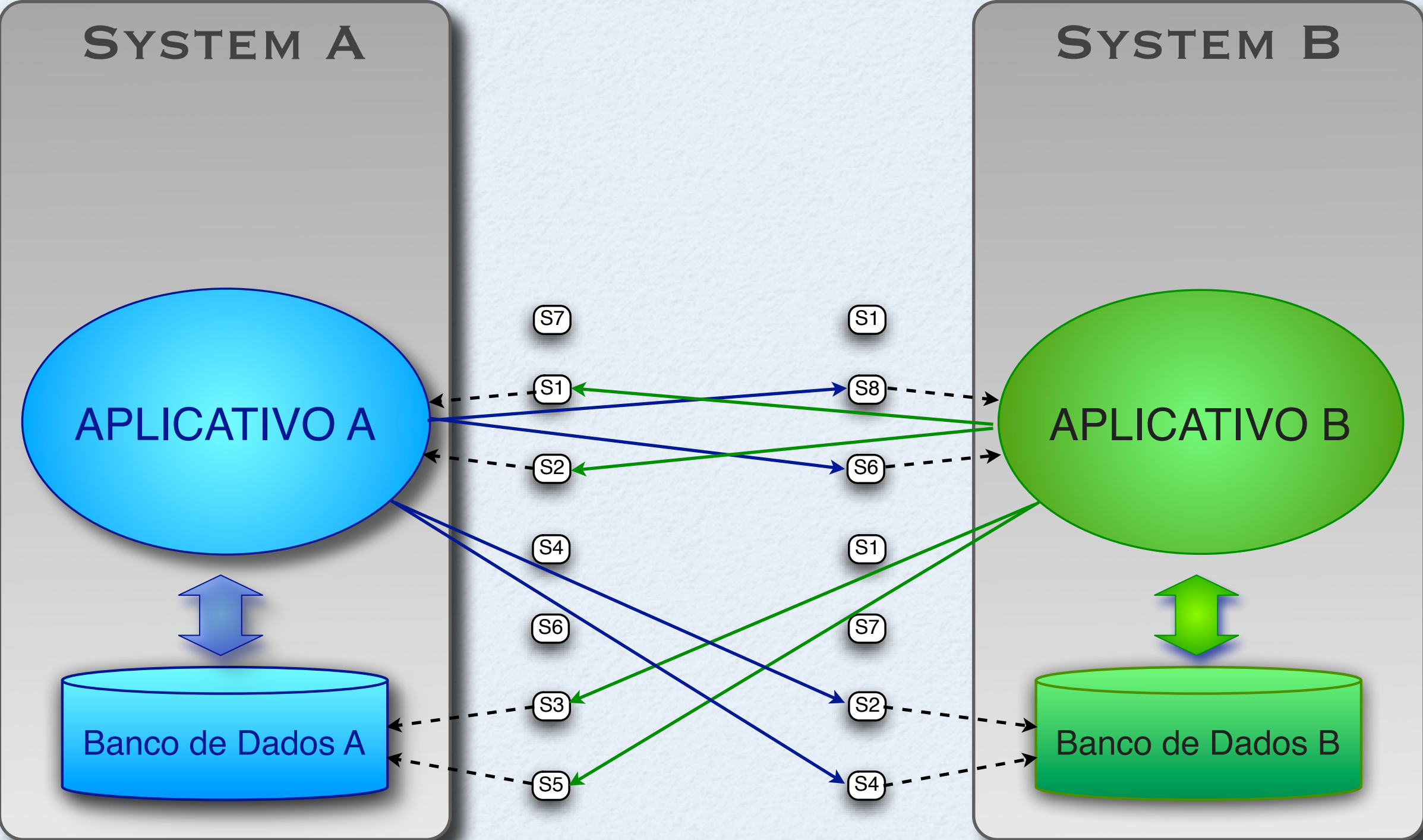


SYSTEM INTERACTION



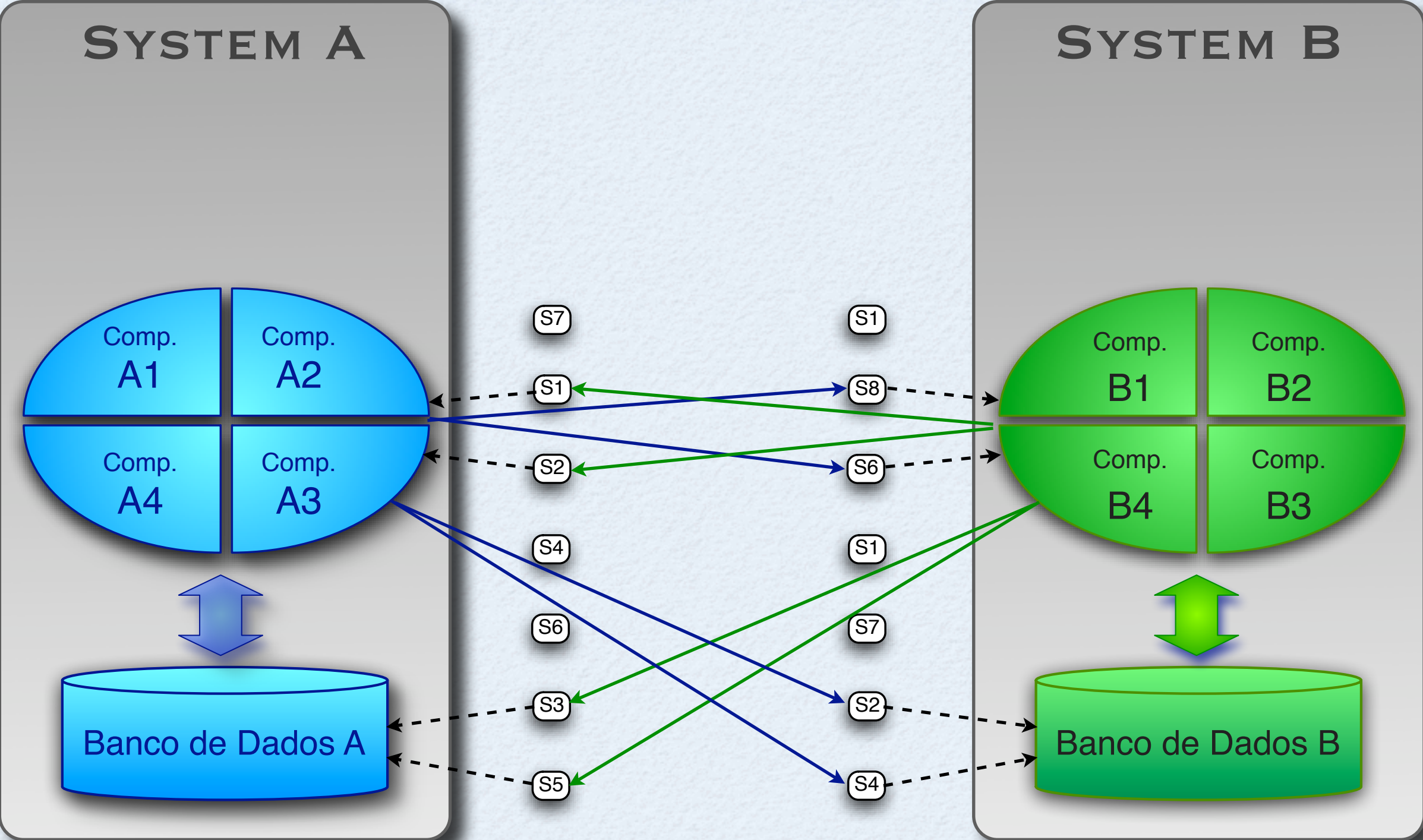
Data
Integration

SYSTEM INTERACTION



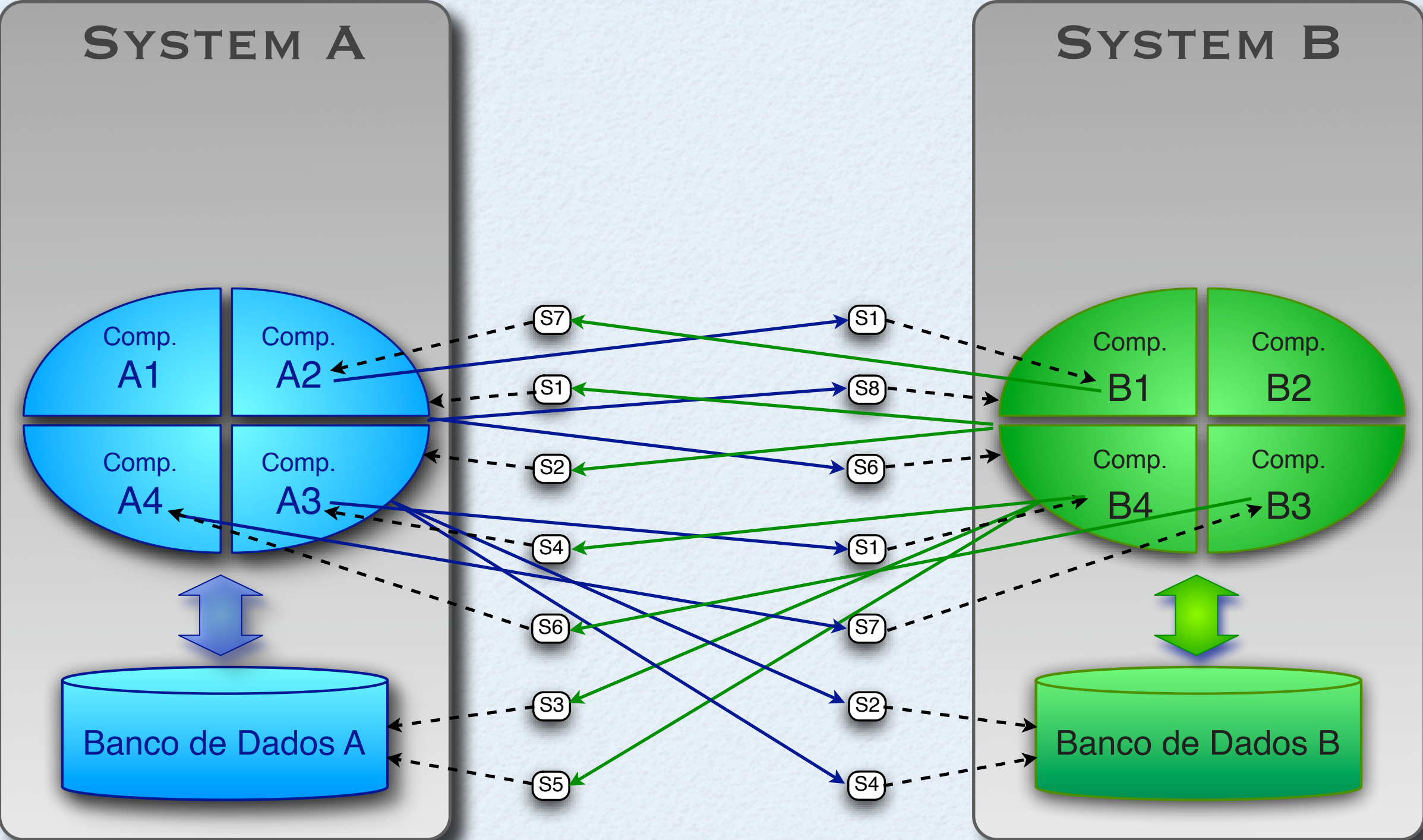
Data Integration	Application Integration
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SYSTEM INTERACTION



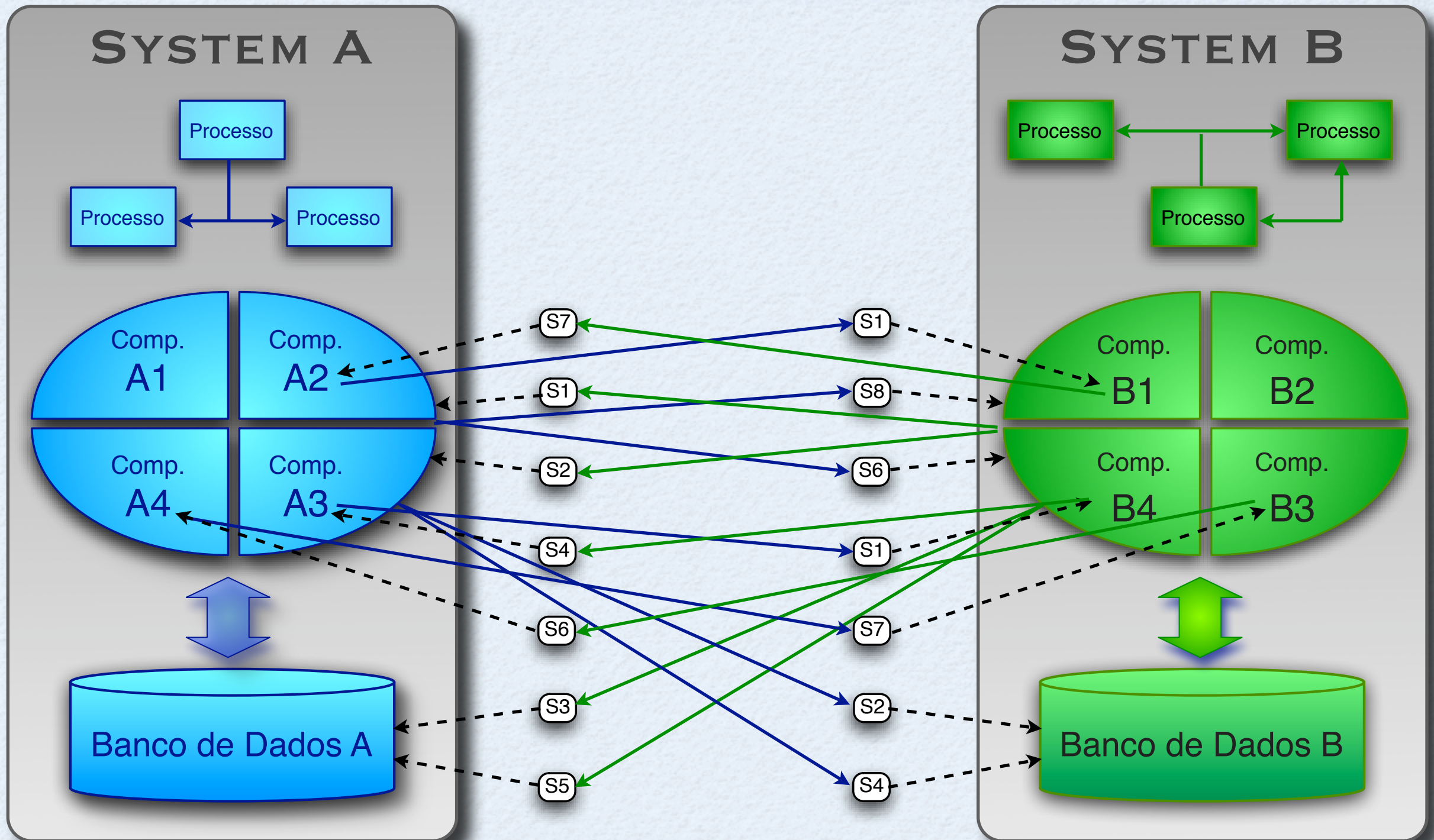
Data Integration	Application Integration
------------------	-------------------------

SYSTEM INTERACTION



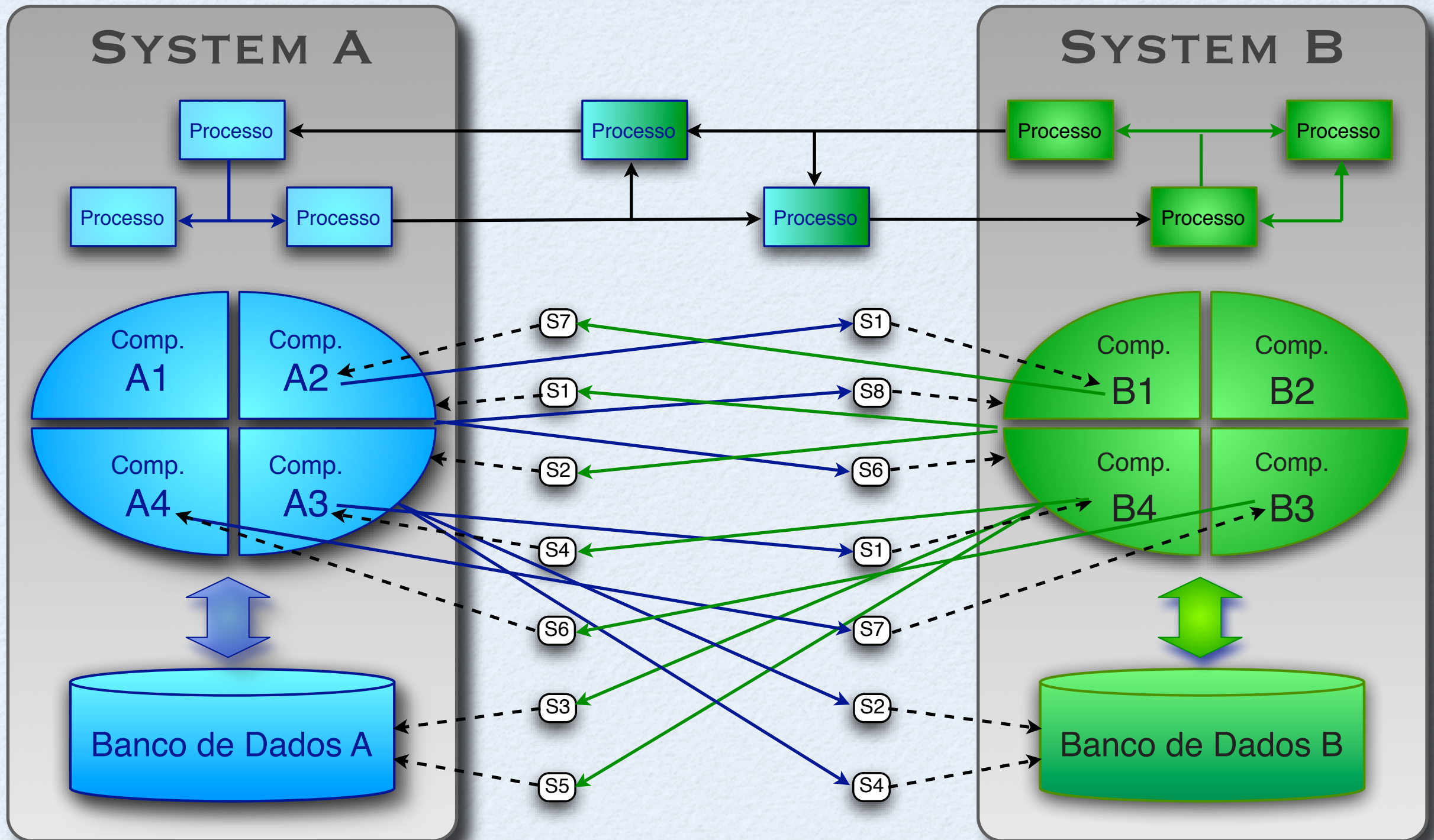
Data Integration	Application Integration	Funcional Integration
------------------	-------------------------	-----------------------

SYSTEM INTERACTION



Data Integration	Application Integration	Funcional Integration
------------------	-------------------------	-----------------------

SYSTEM INTERACTION



Data Integration	Application Integration	Funcional Integration	Process Integration
------------------	-------------------------	-----------------------	---------------------