Probabilistic Ontologies for Efficient Resource Sharing in Semantic Web Services

Paulo Cesar G. da Costa
Kathryn B. Laskey
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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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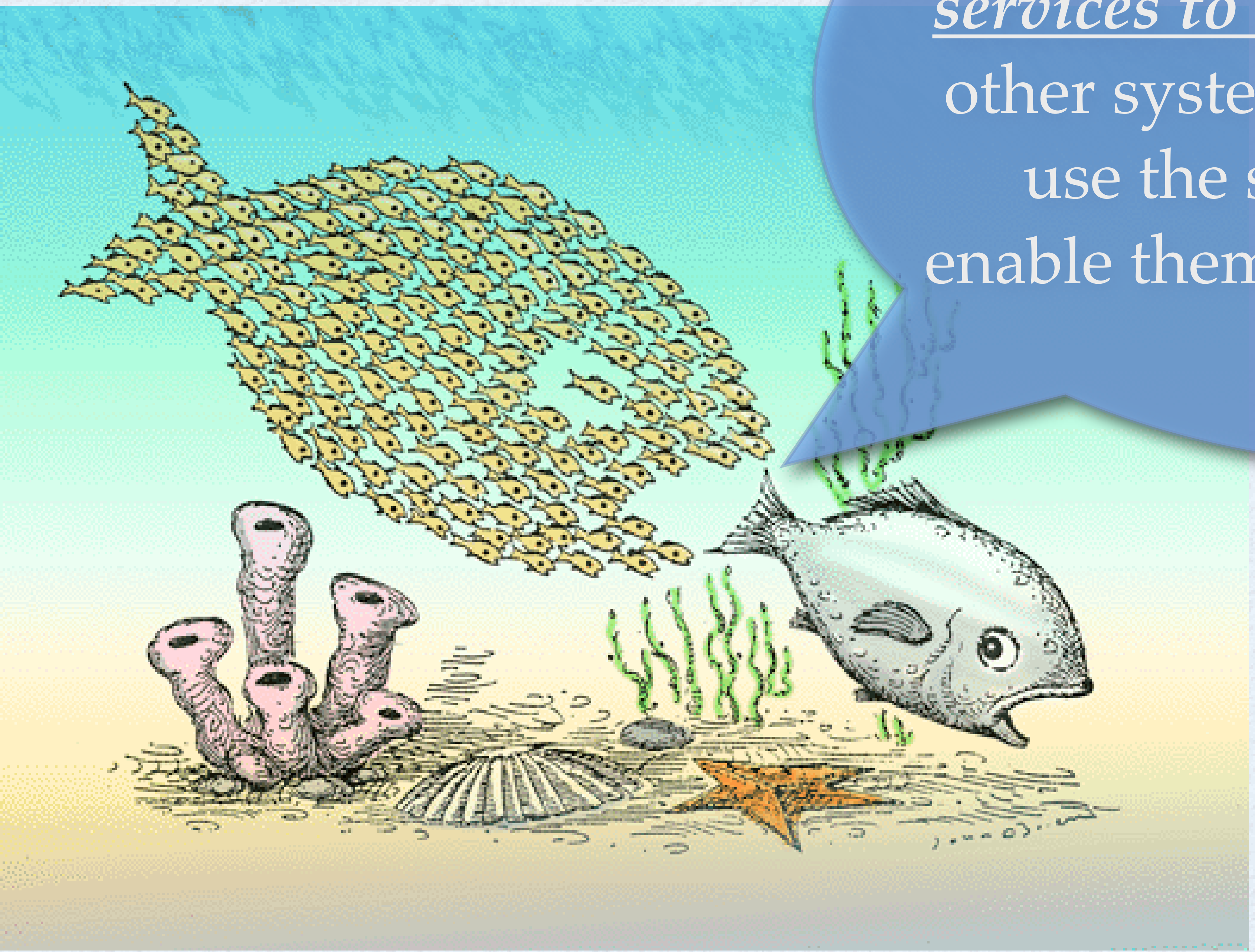
Interoperability?

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.



http://en.wikipedia.org/wiki/Interoperability

We need explicit semantics!

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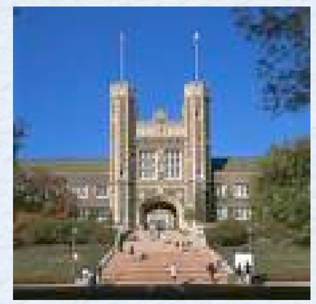
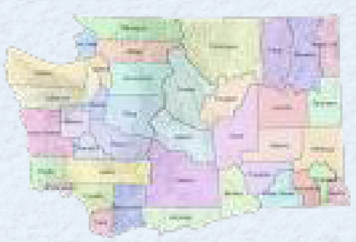
"Washington voiced strong objections to the proposed policy..."

We need explicit semantics!


The University?


The football team?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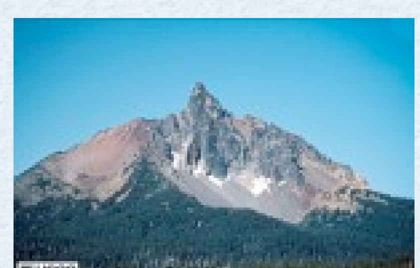
"Washington voiced strong objections to the proposed policy…"


The city?


The Actor?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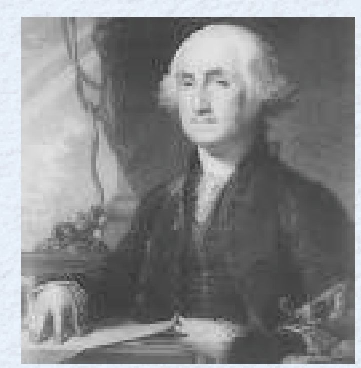
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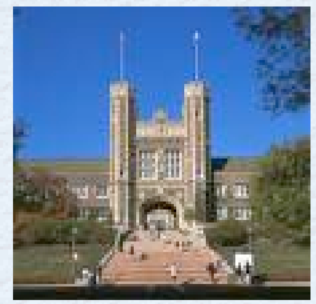

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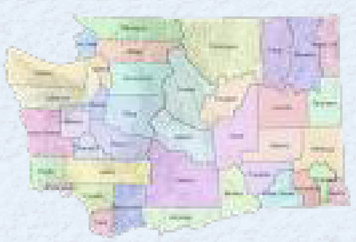

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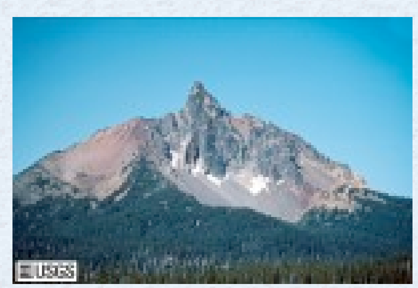

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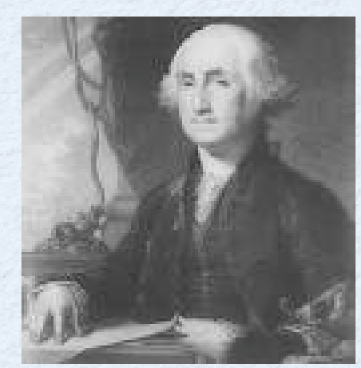

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WHY?

- ★ 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?

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★ 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

PROBLEM SOLVED!!!

>>> ONTOLOGIES <<<

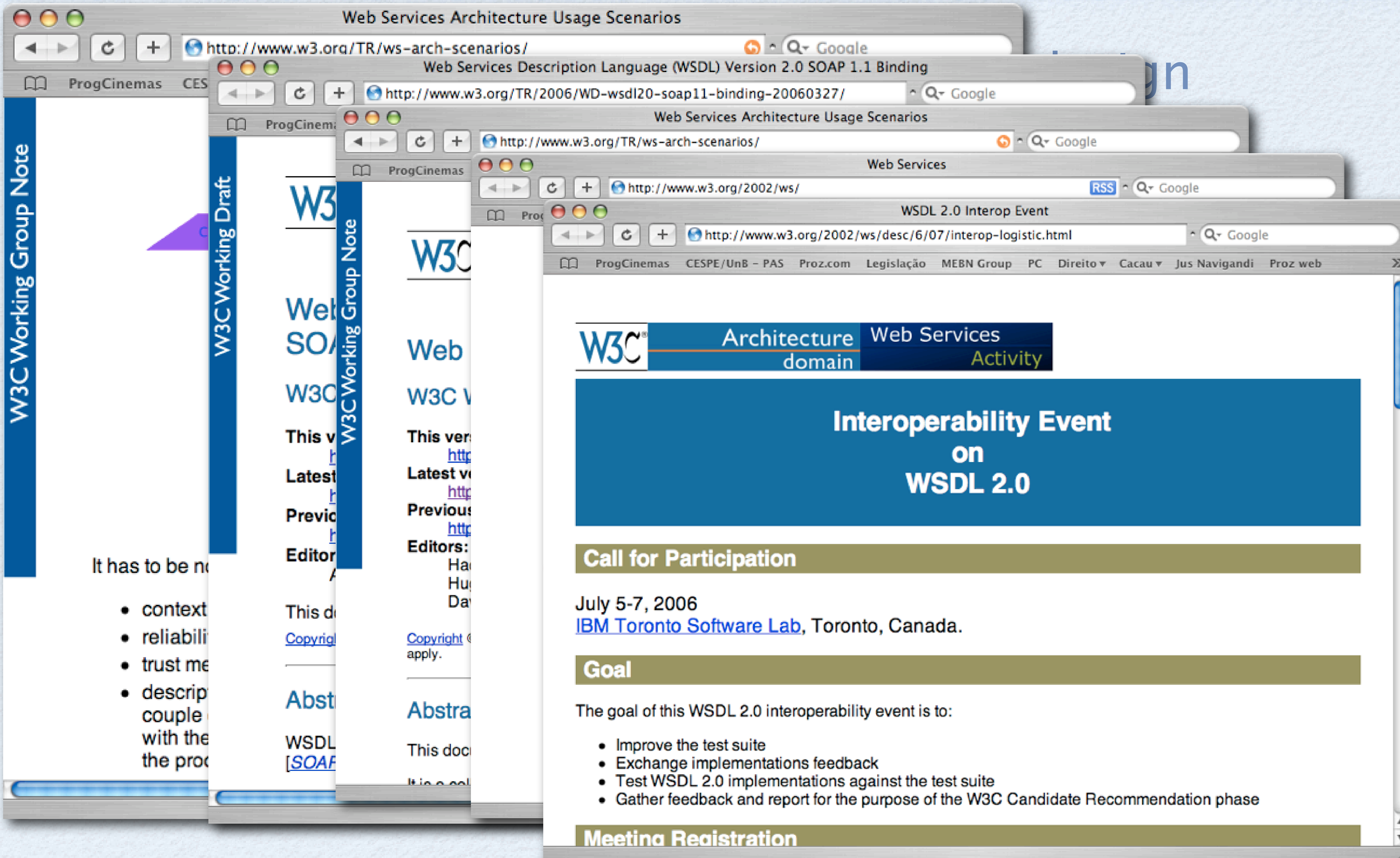
SAVED THE DAY

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



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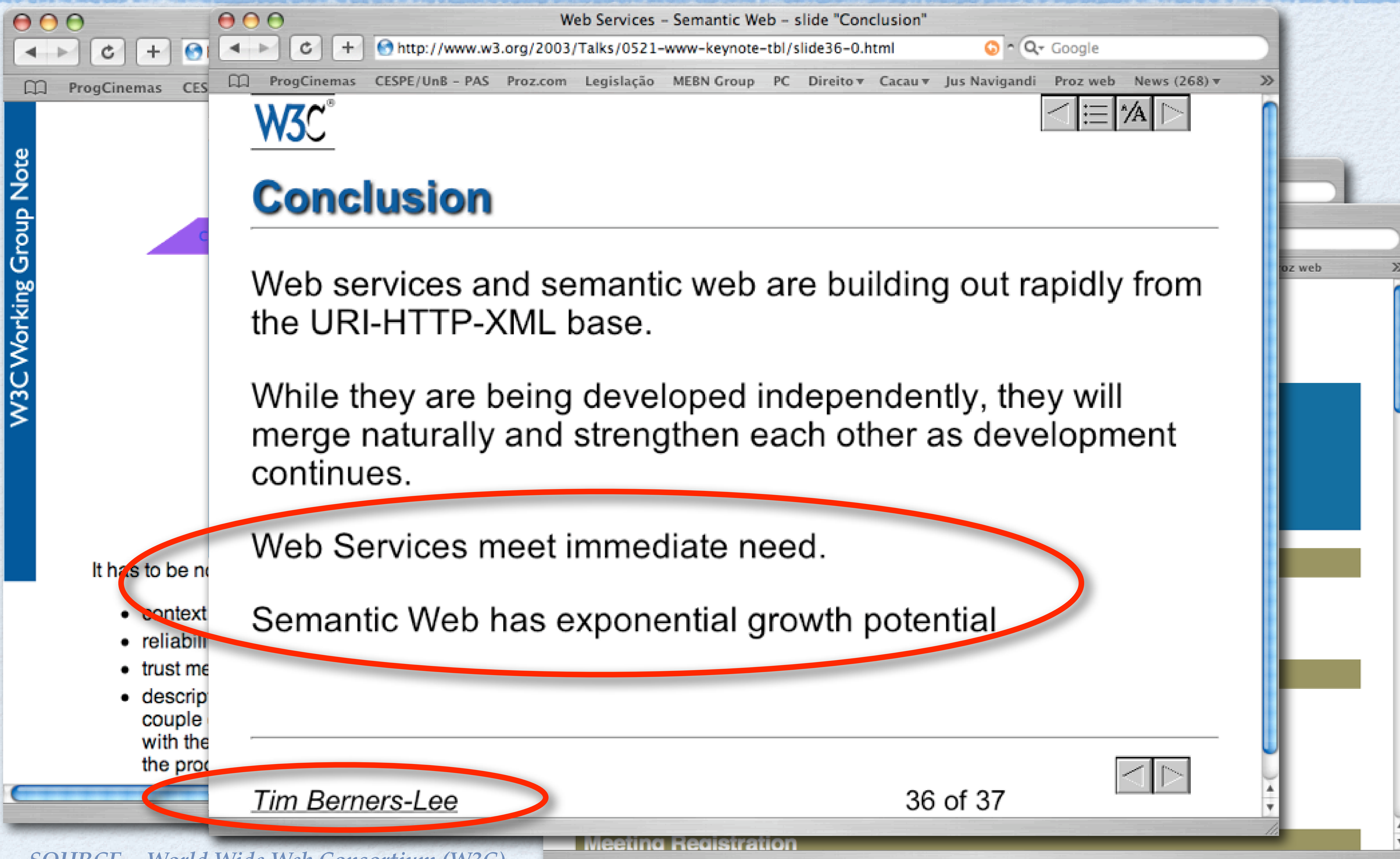

SOURCE = World Wide Web Consortium (W3C)

Web Services?

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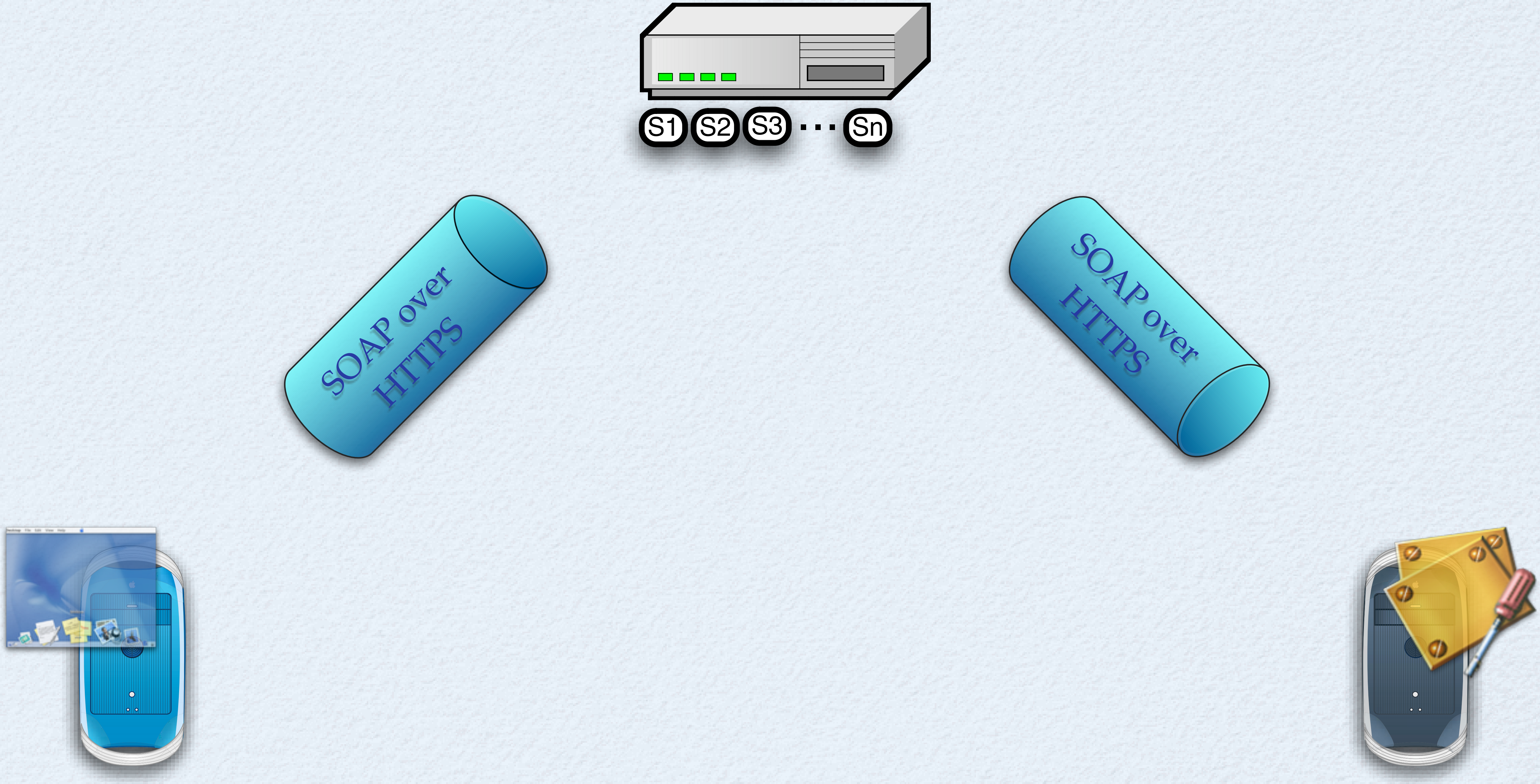

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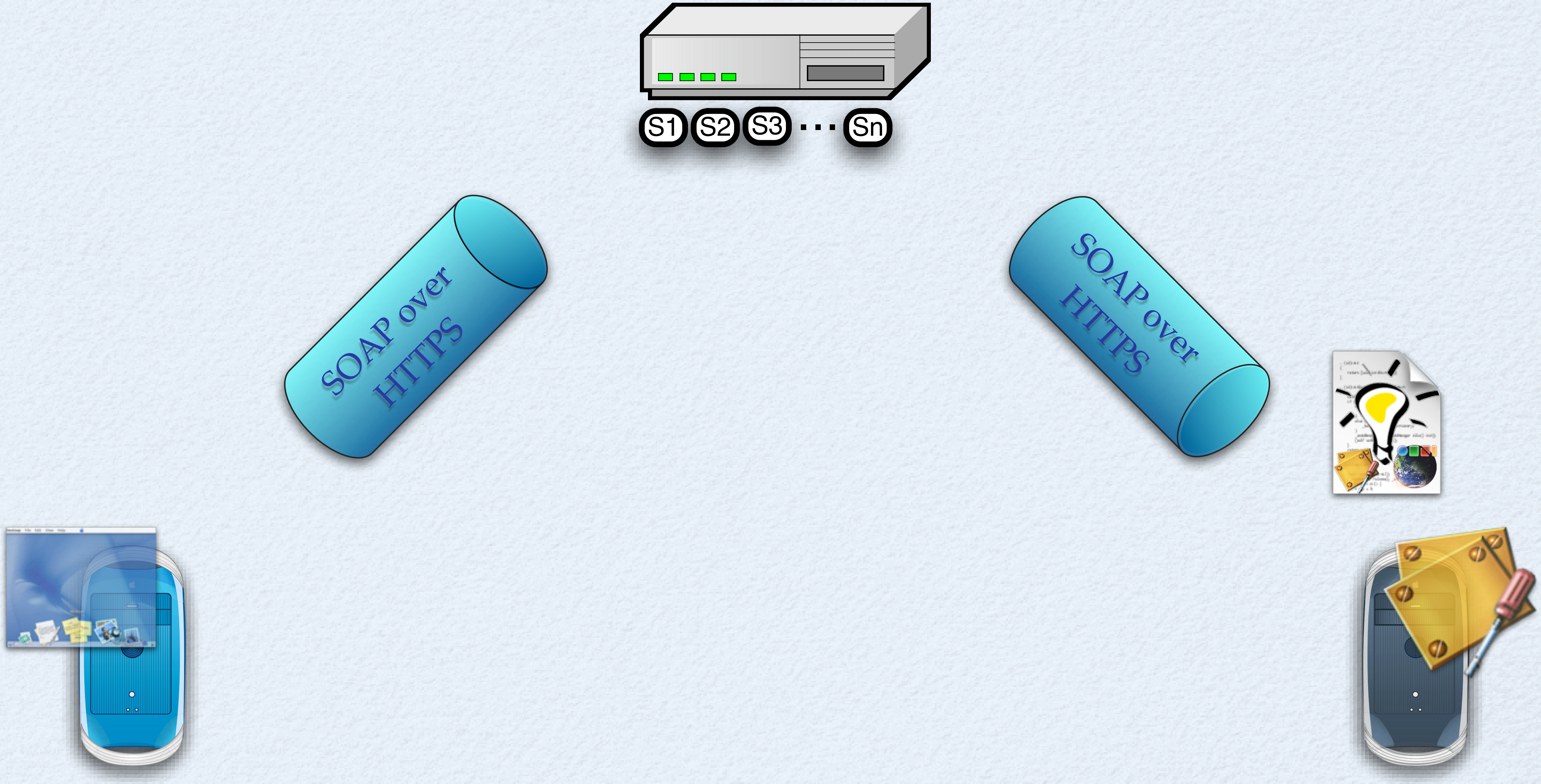

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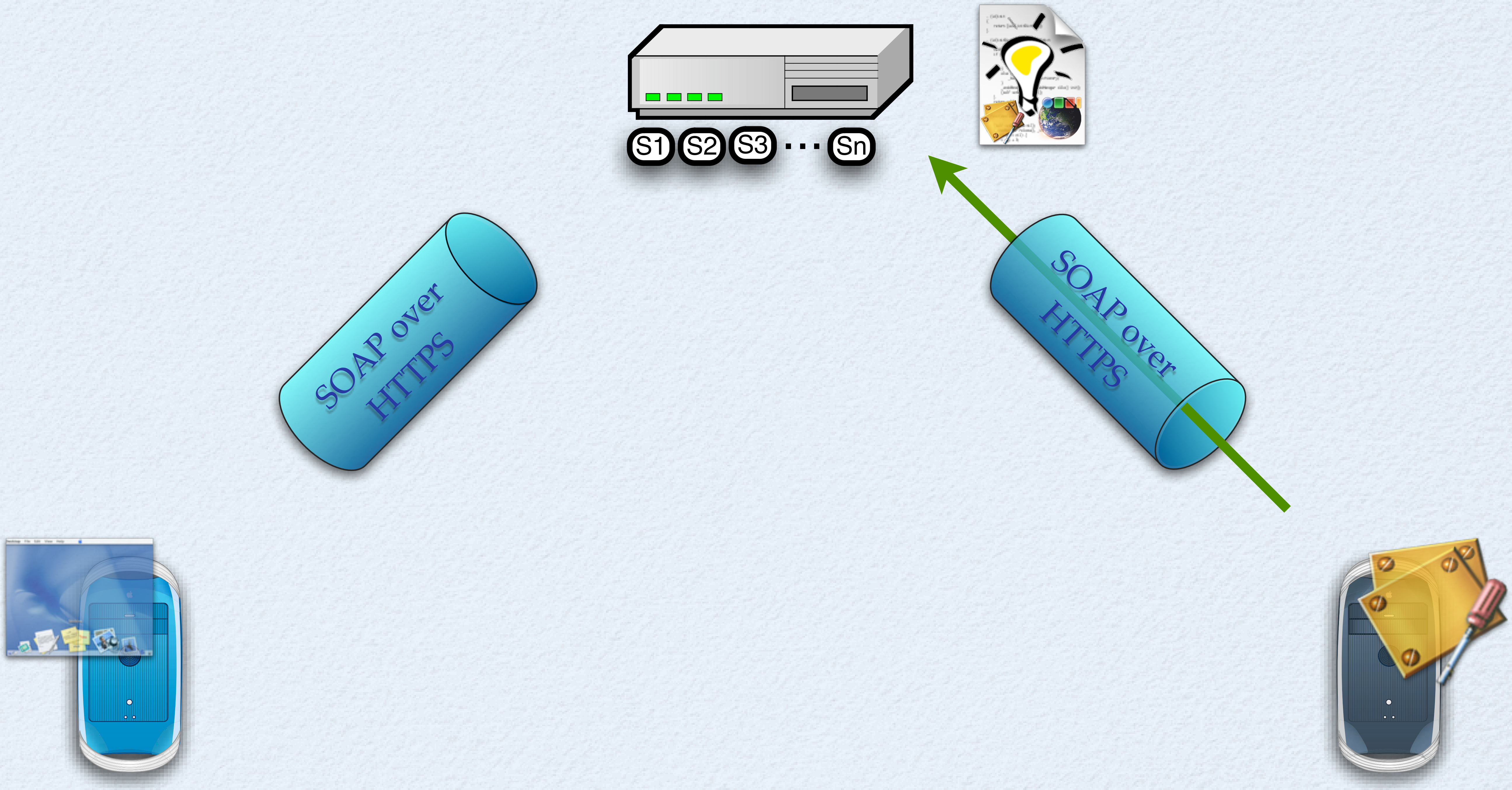

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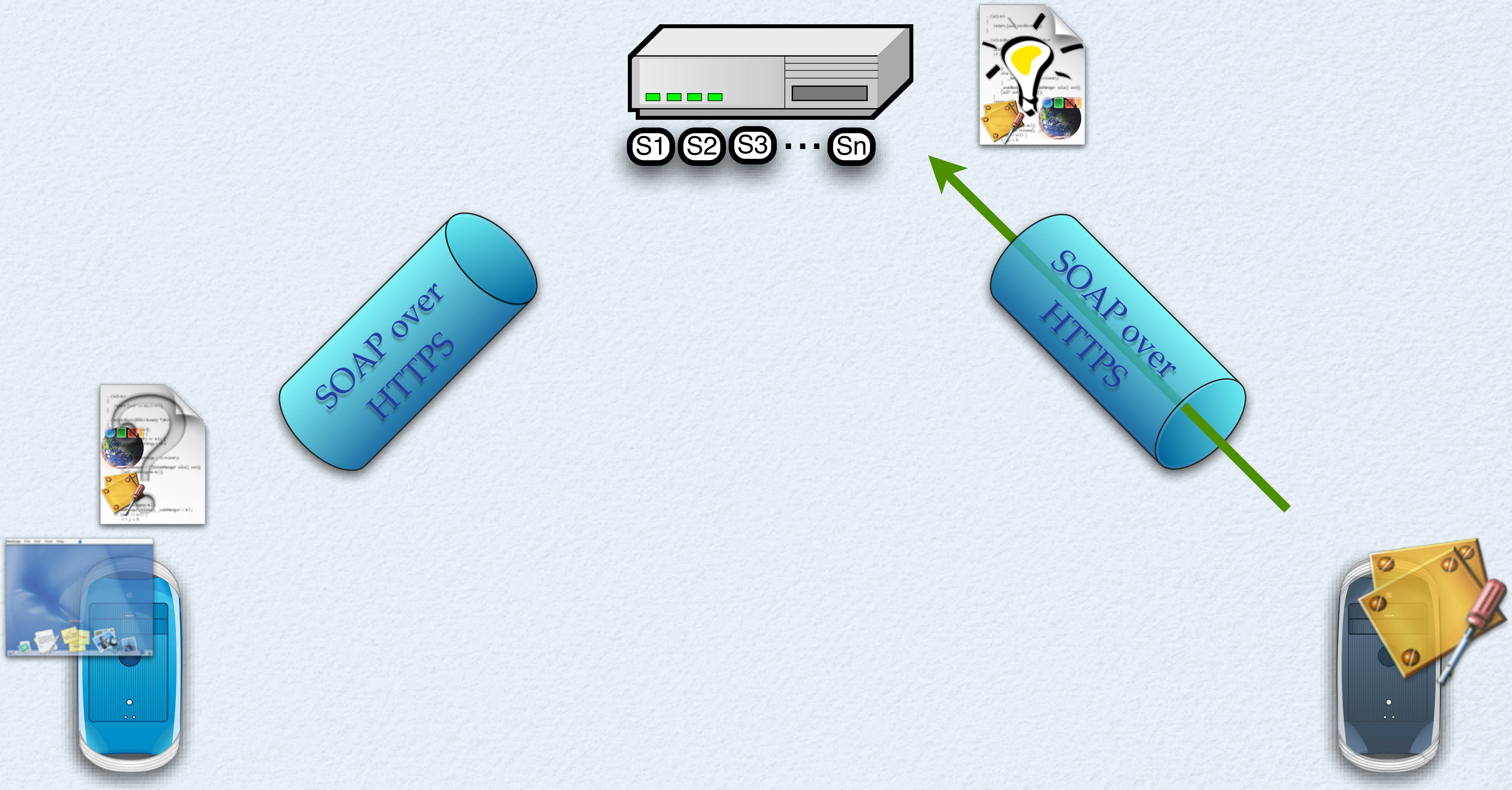

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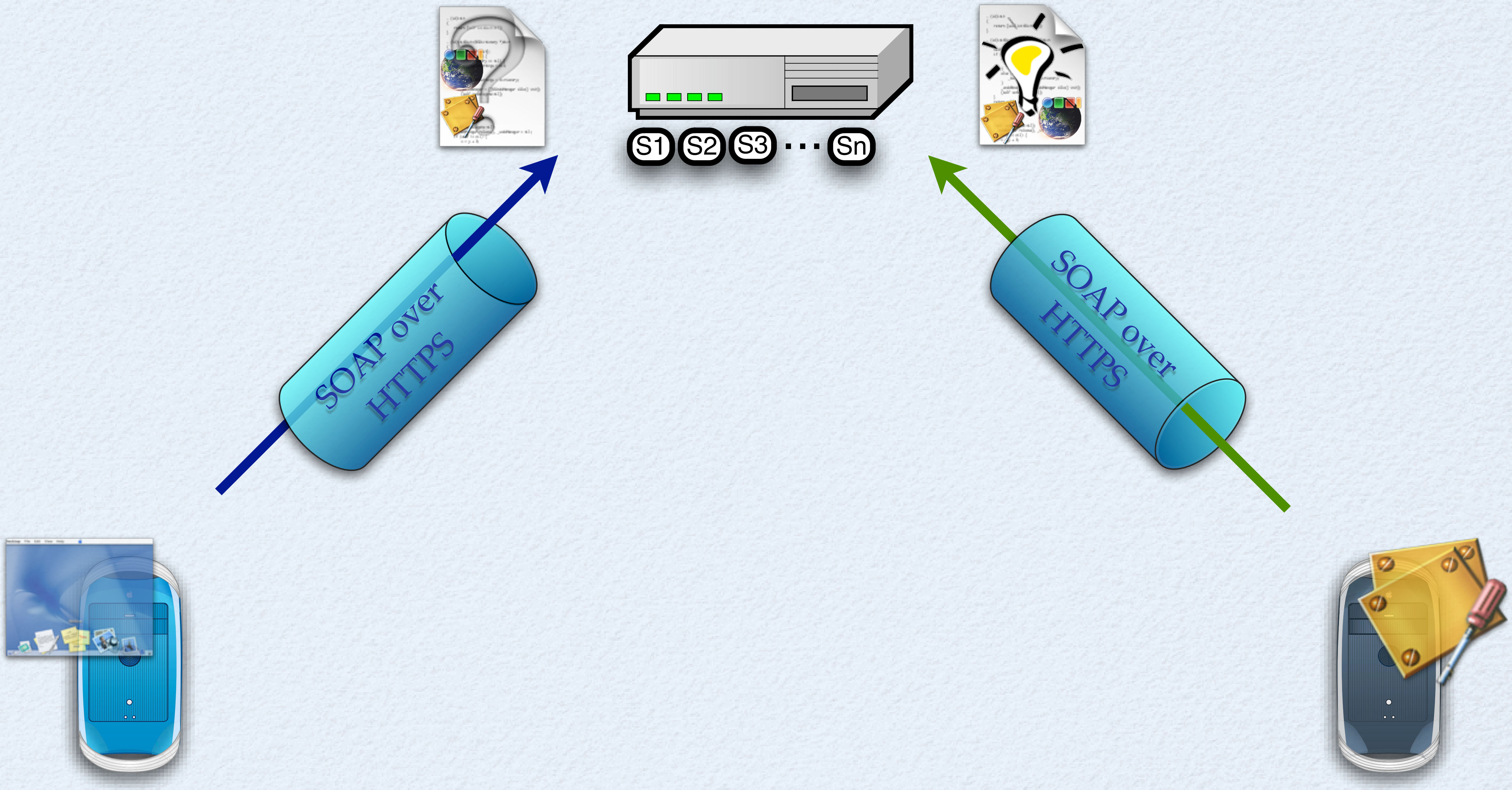

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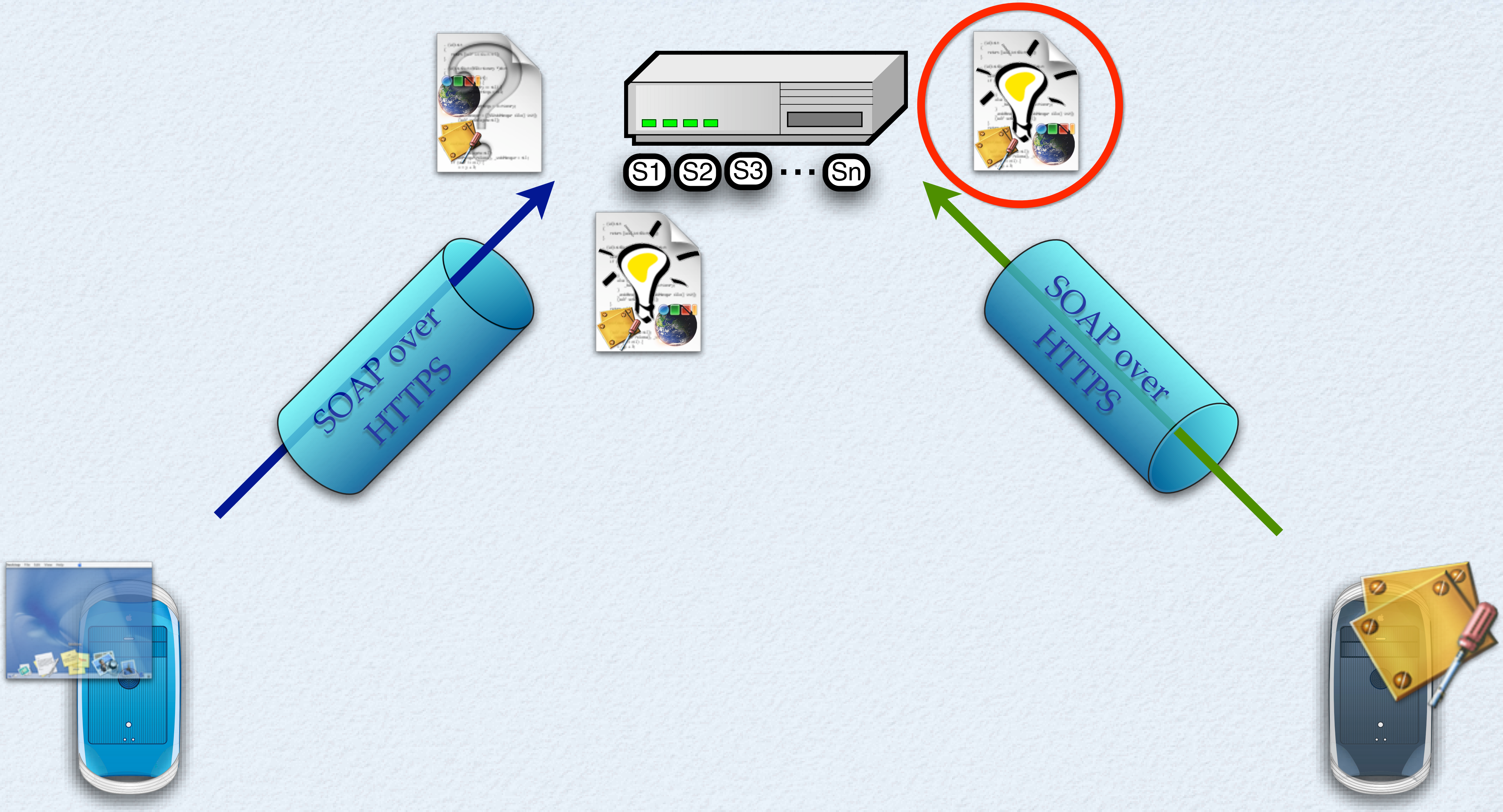

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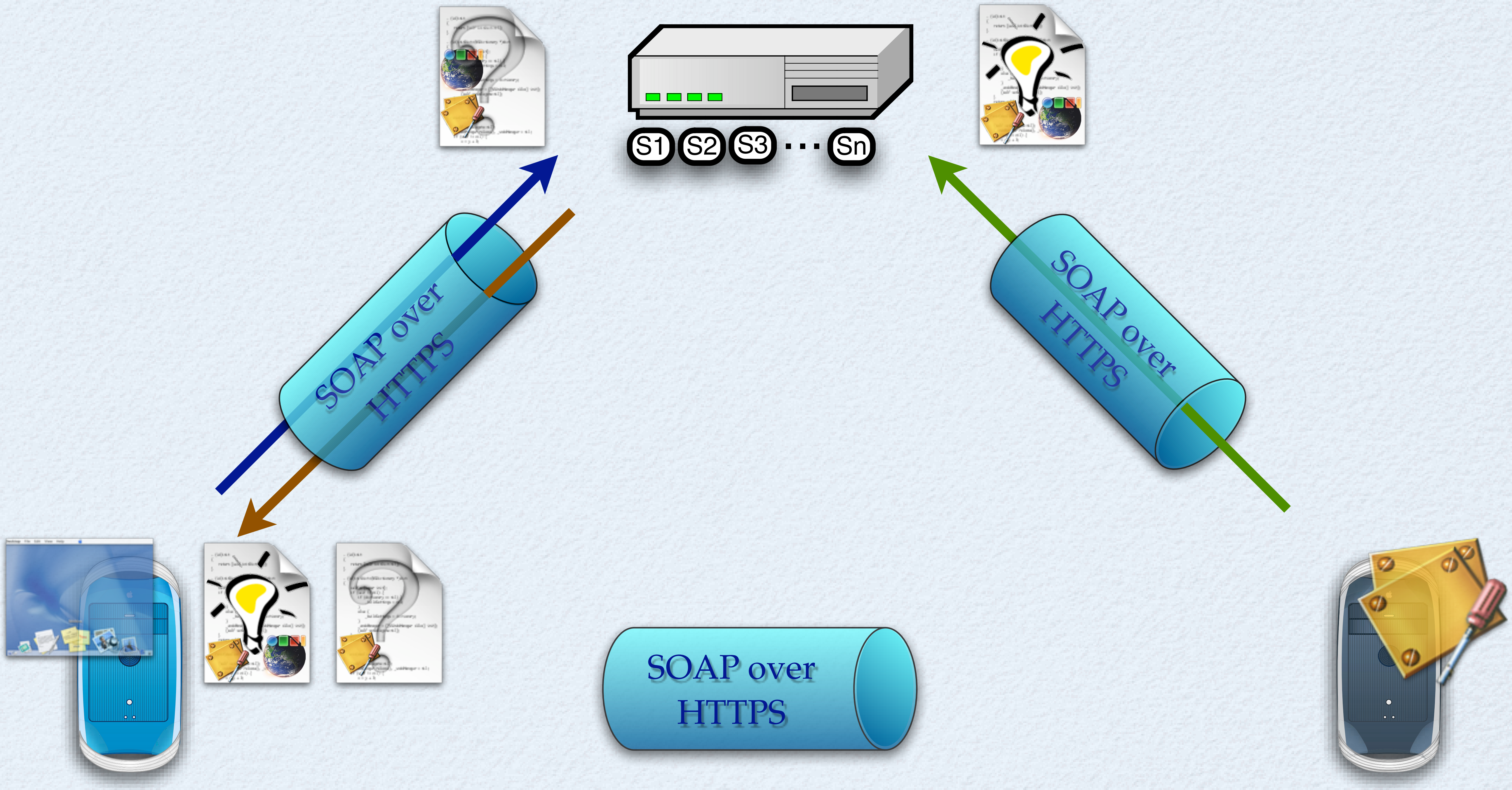

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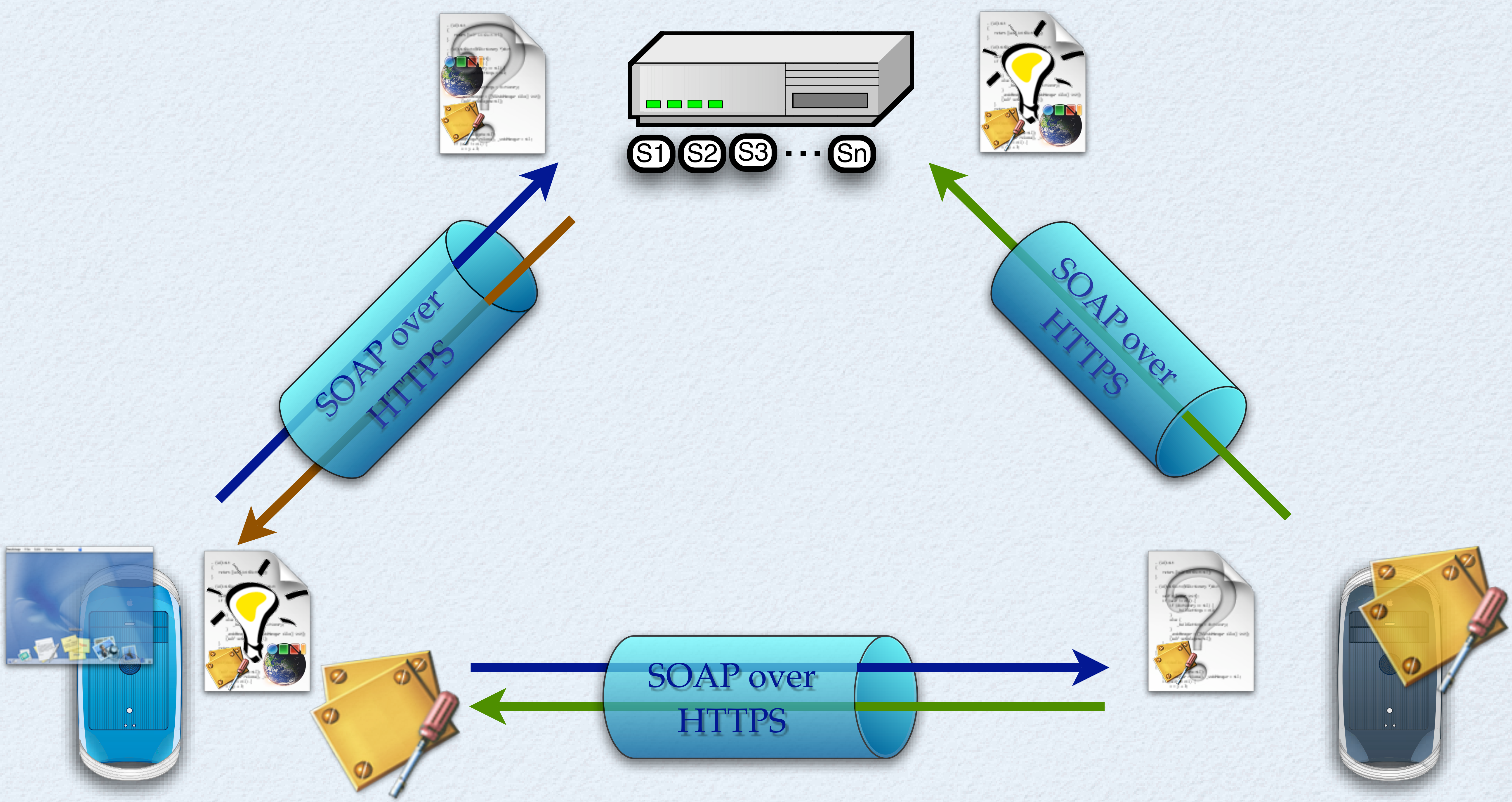
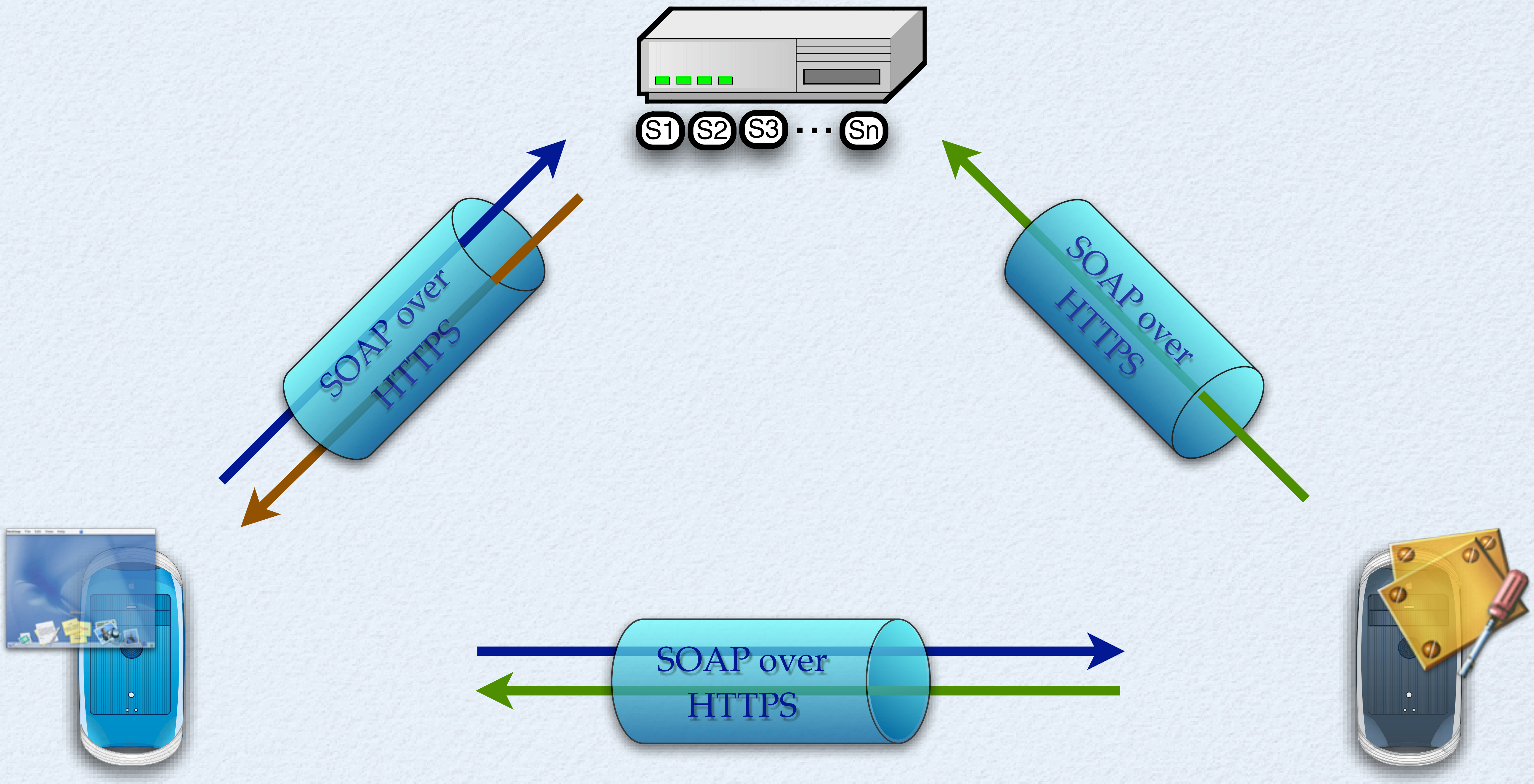


THE P-F-B TRIANGLE



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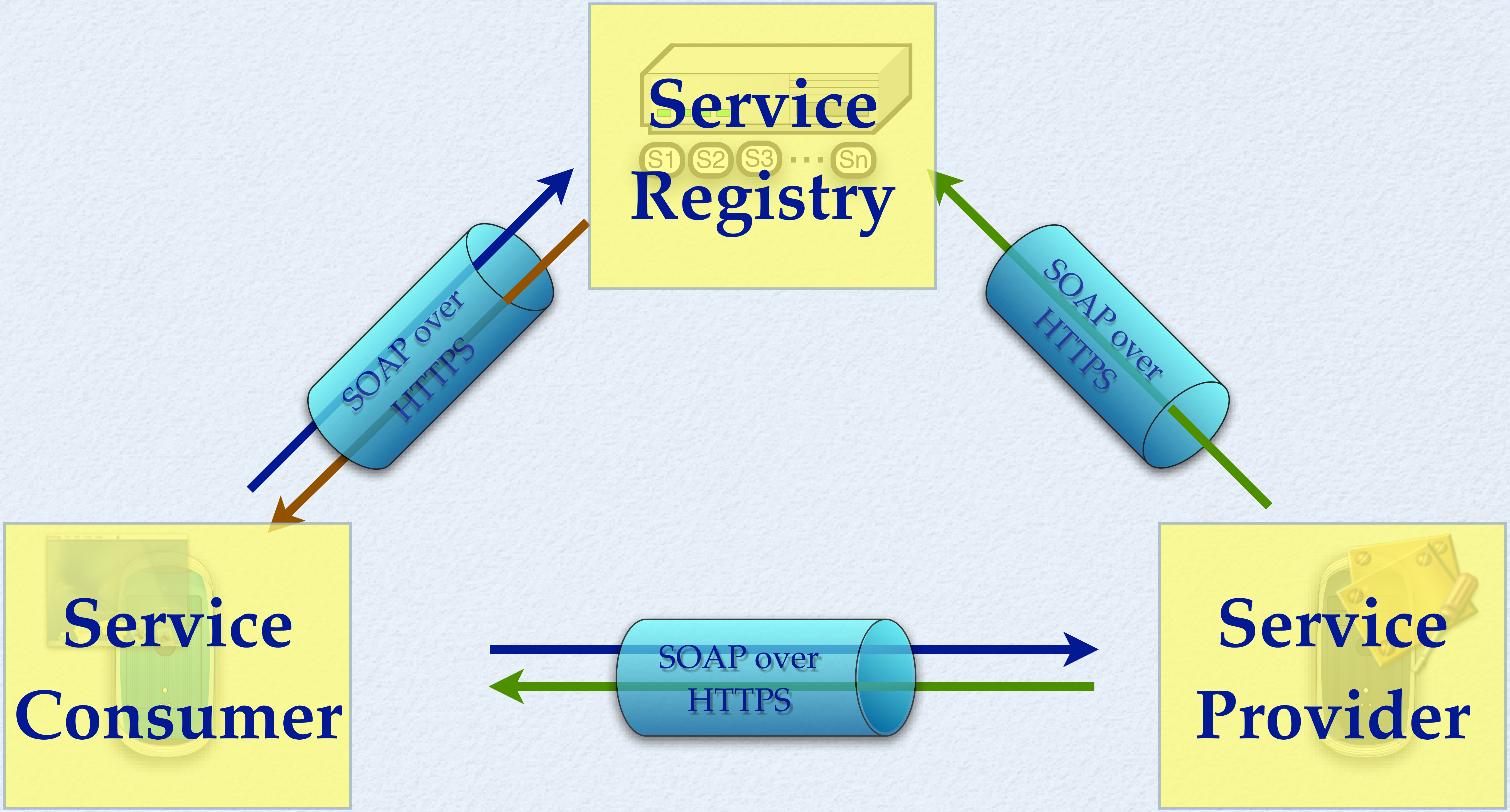

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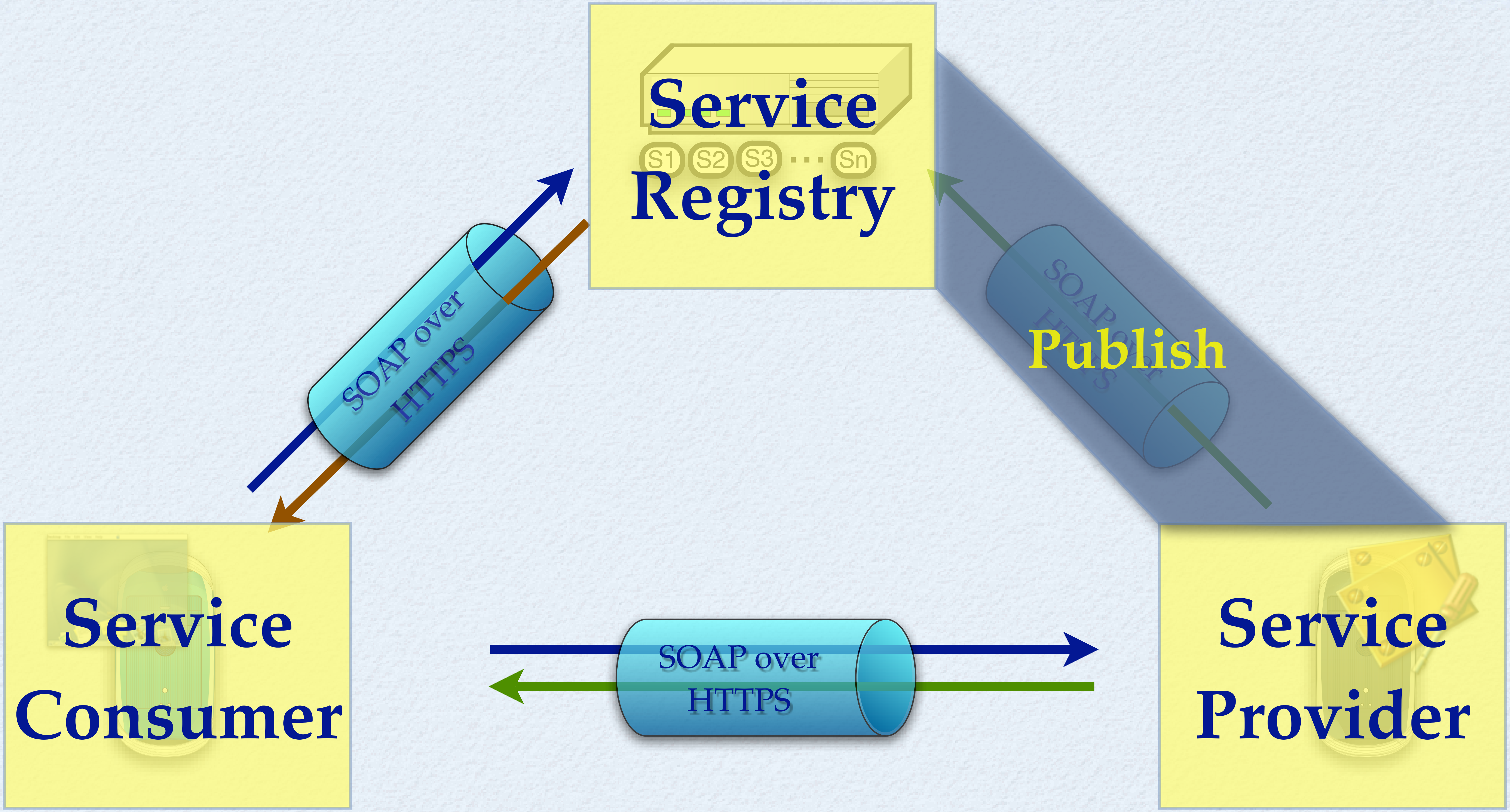

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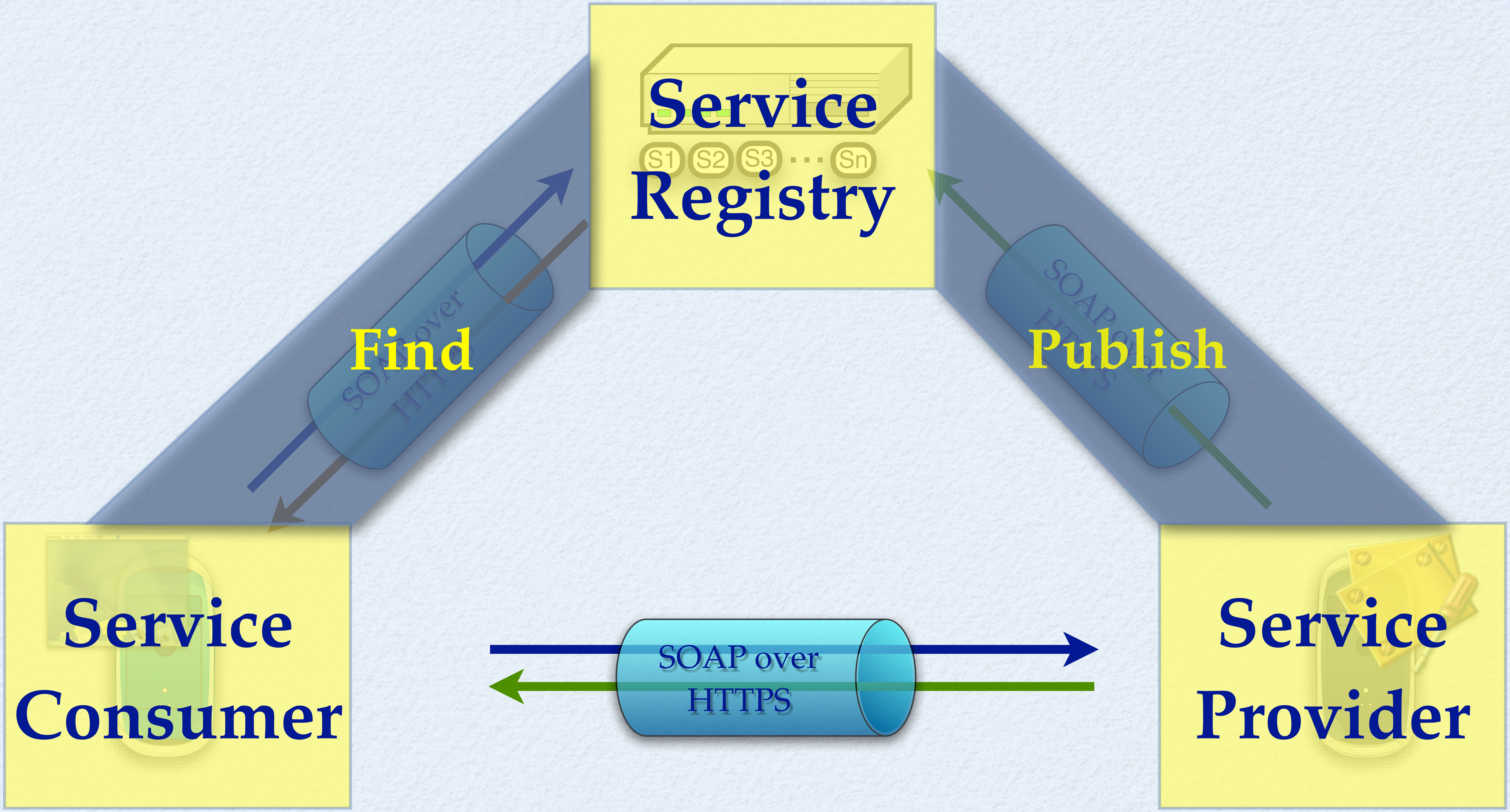

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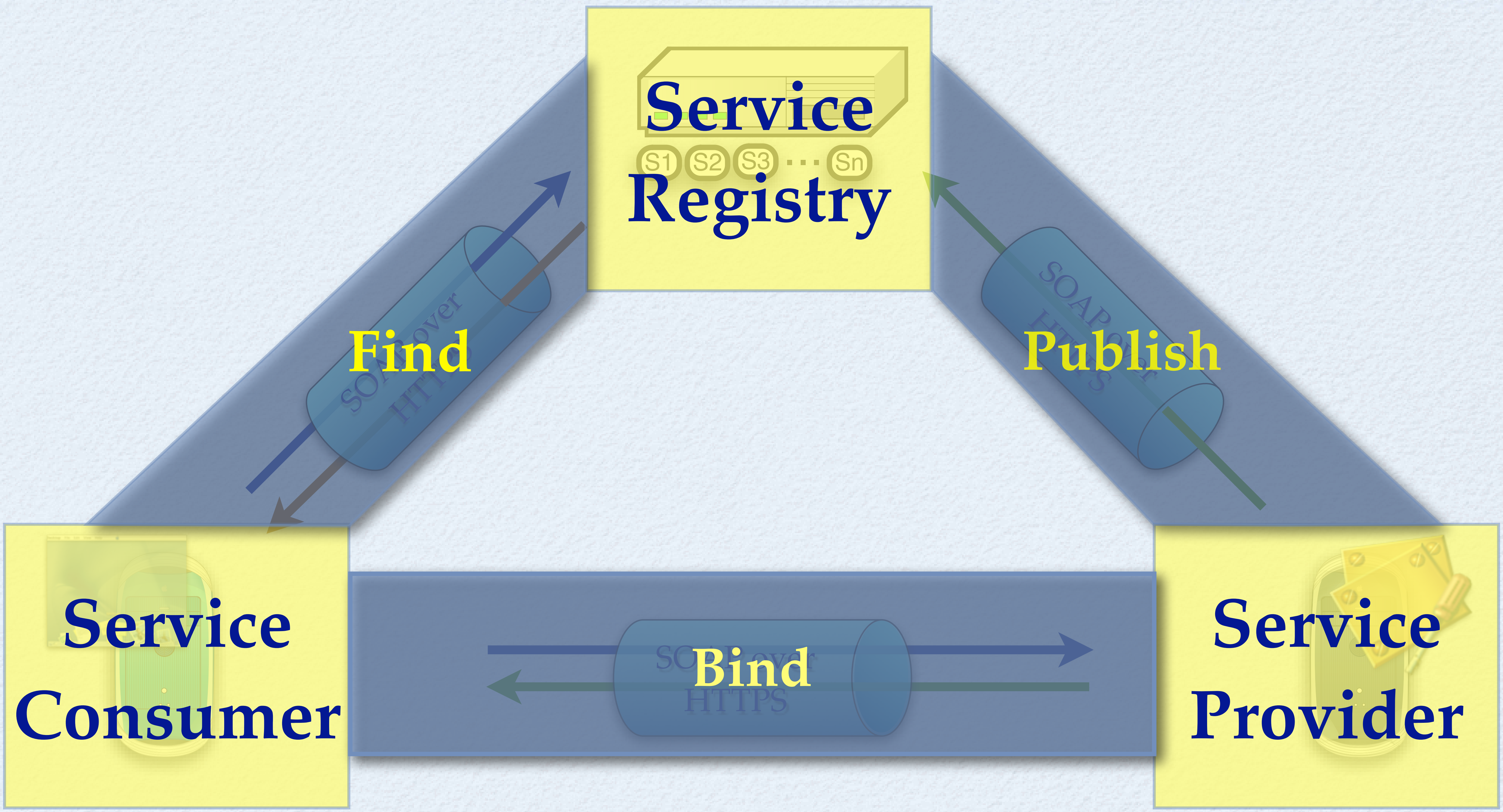
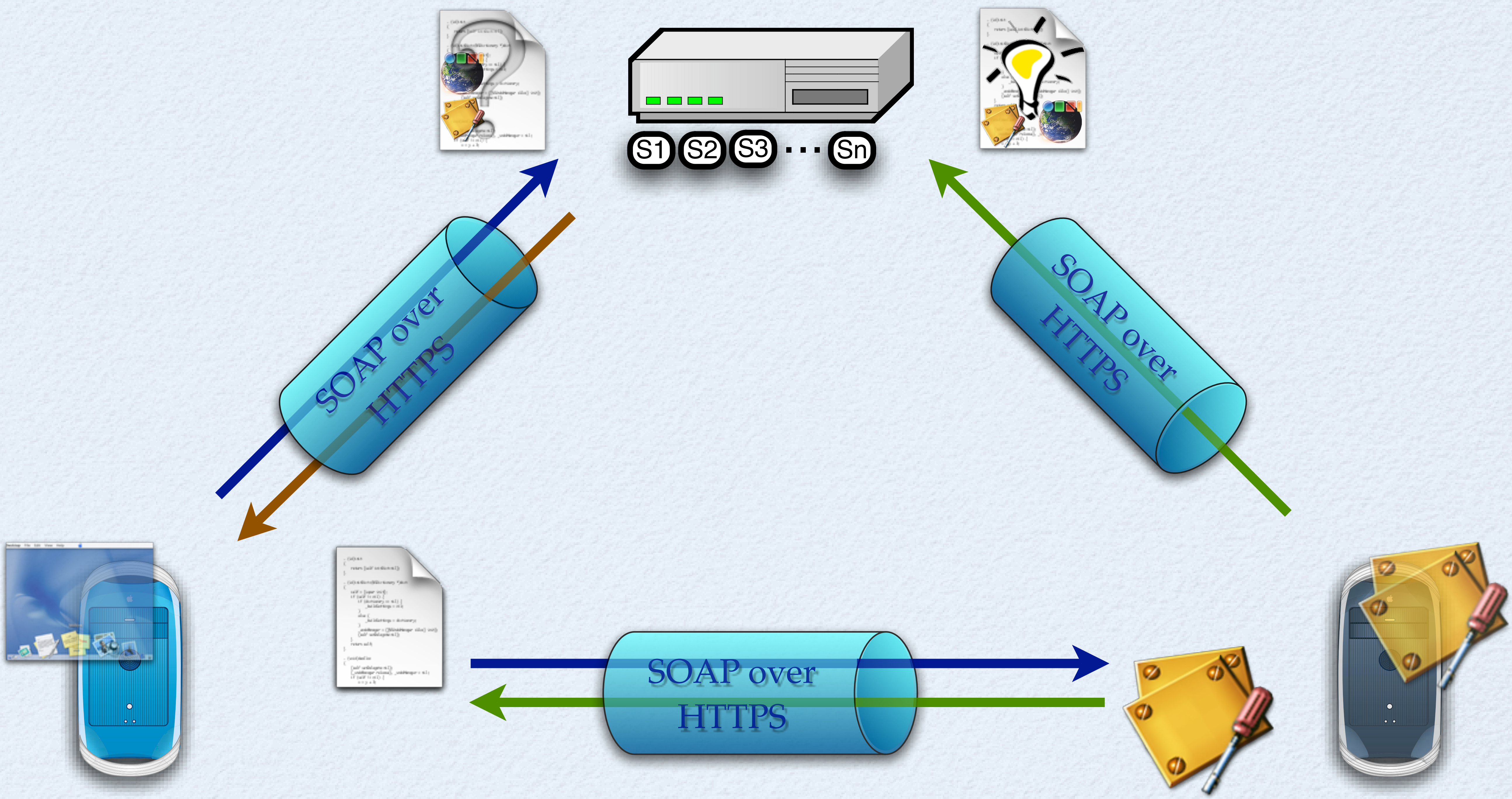


Do we need Semantics?



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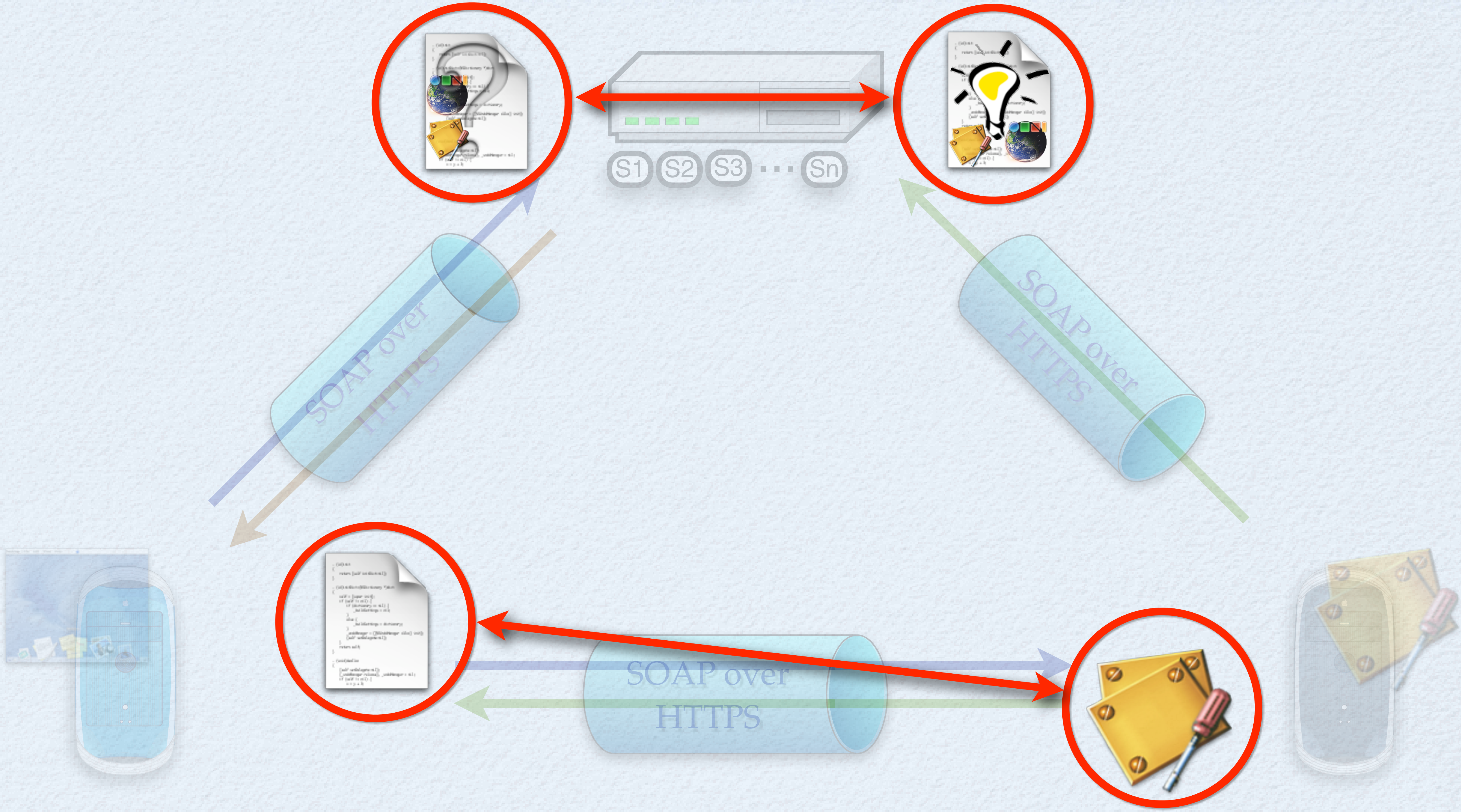

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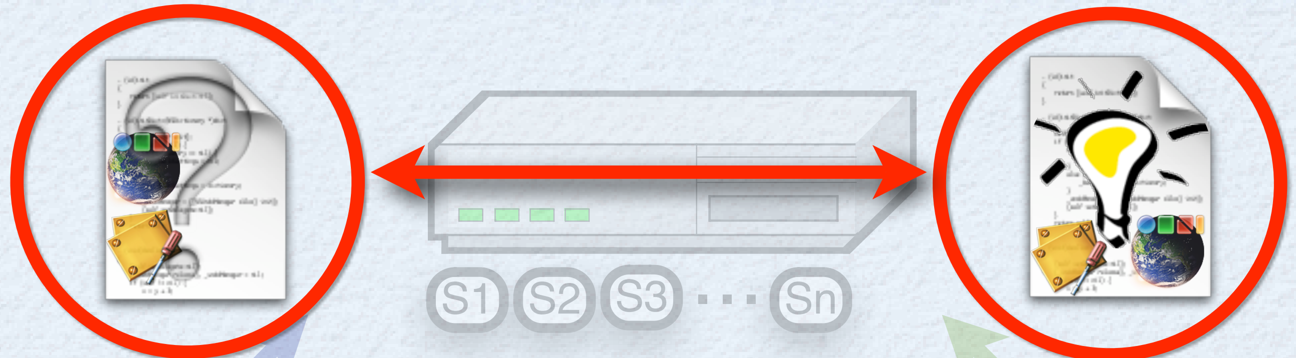

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  - Syntax means rules of formation for a data type
  - Syntactic interoperability means an application can process the data formats produced by another
  - E.g., 38.2 is a legal floating point number
- **Semantics**
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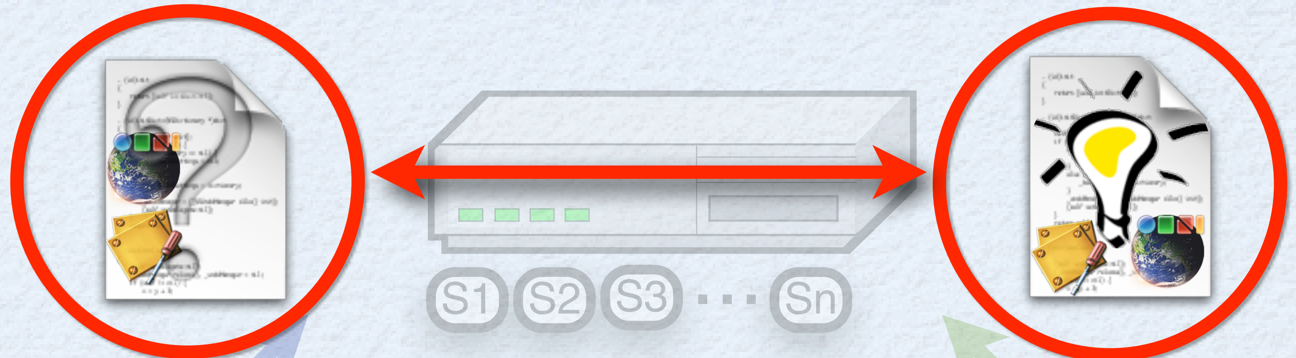

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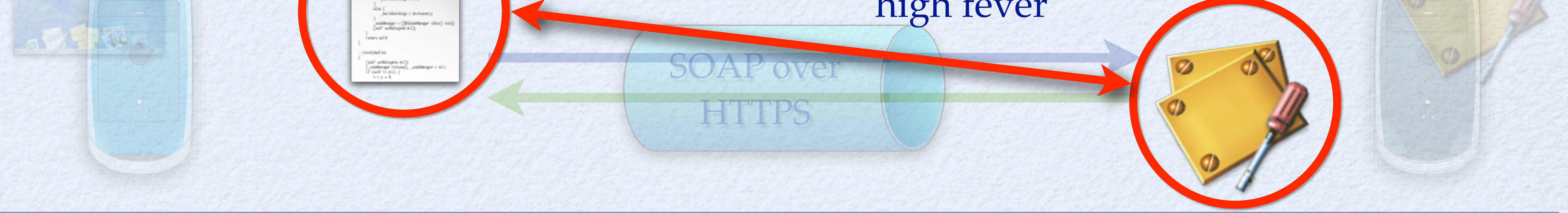
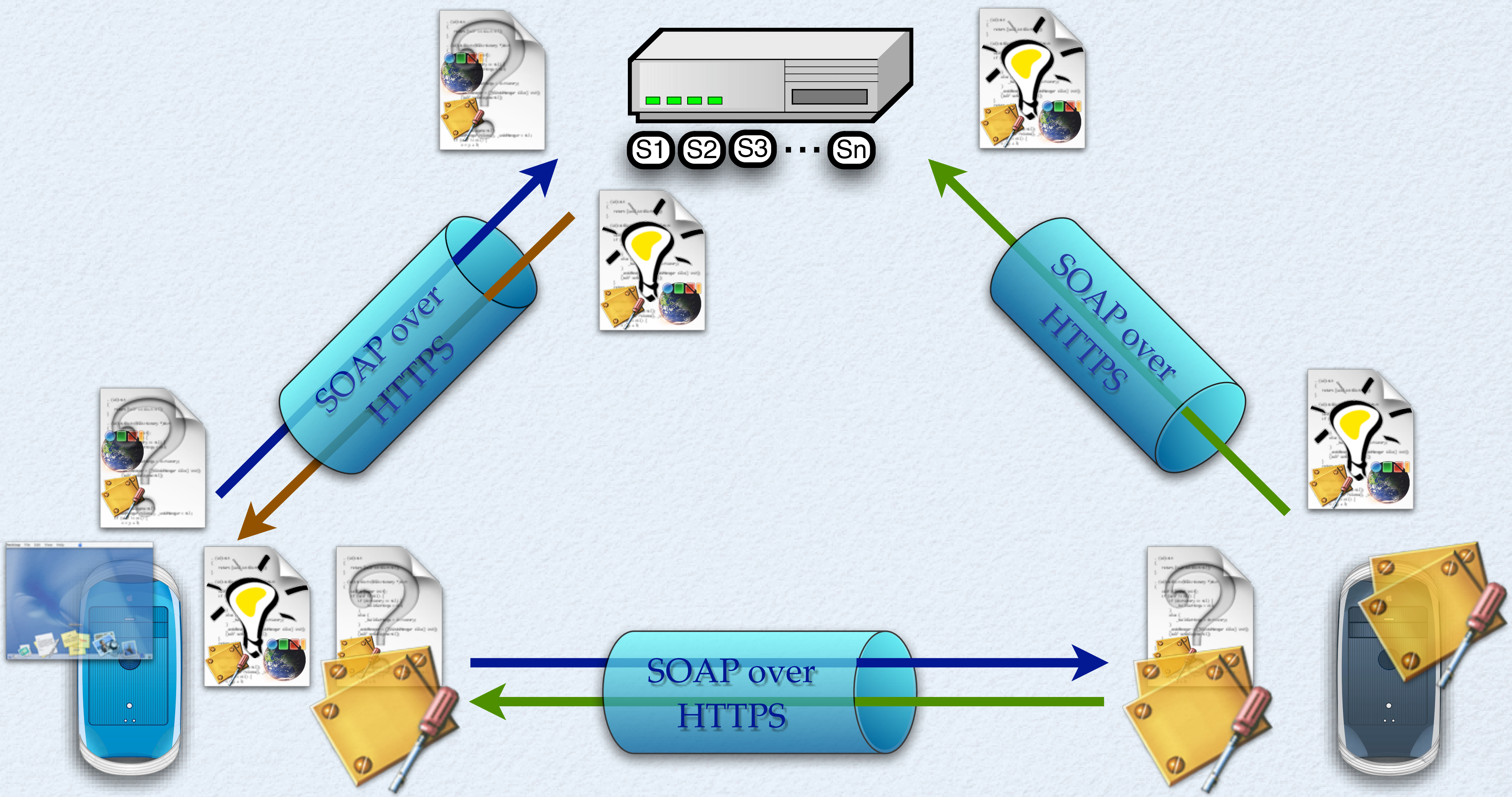


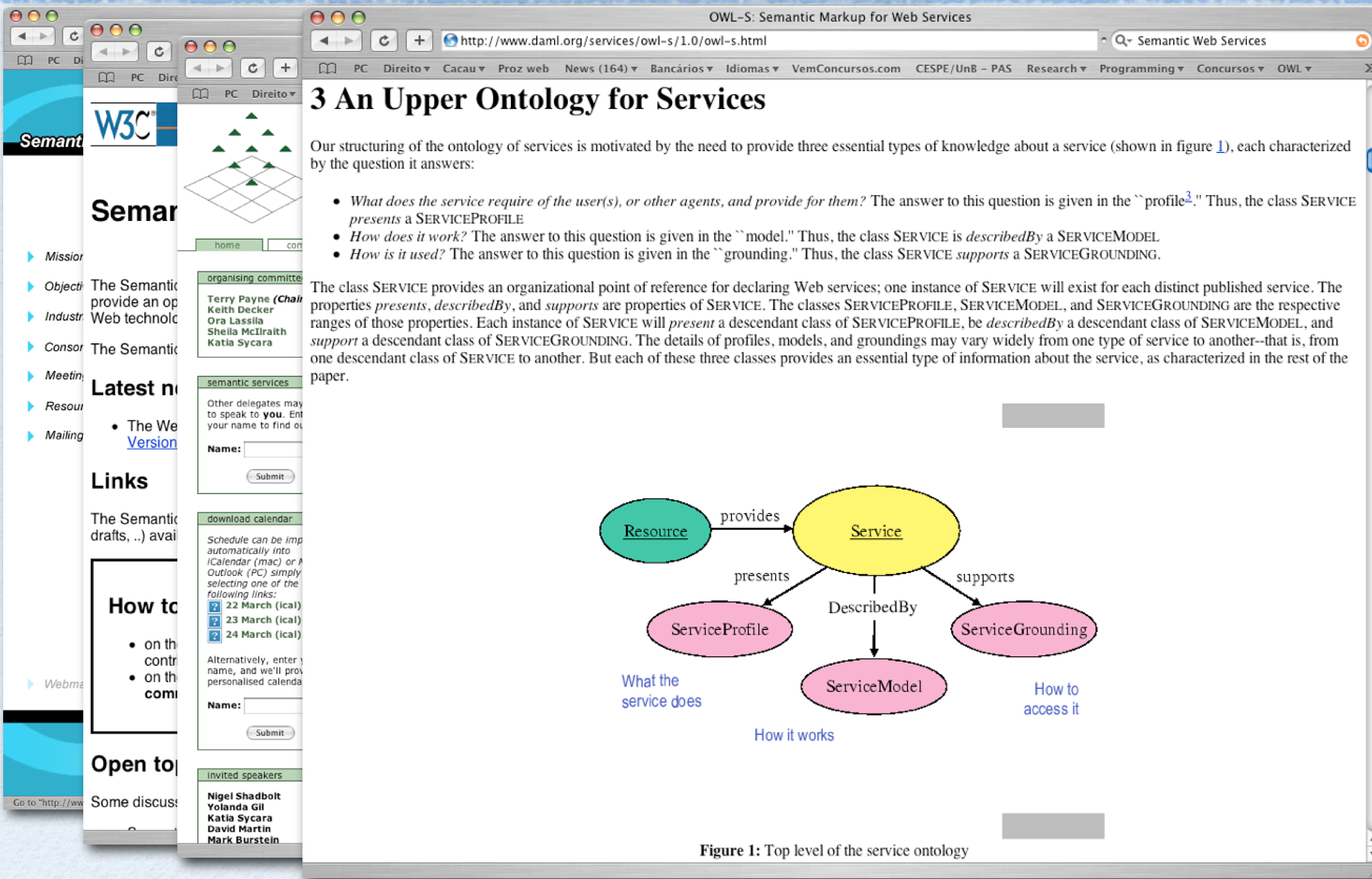
- **Consumers and providers need to agree on semantics of service descriptions**
- **Semantic interoperability is a much stronger requirement than type consistency**


S1
S2
S3
Sn
SOAP over HTTPS
SOAP over HTTPS
SOAP over HTTPS

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



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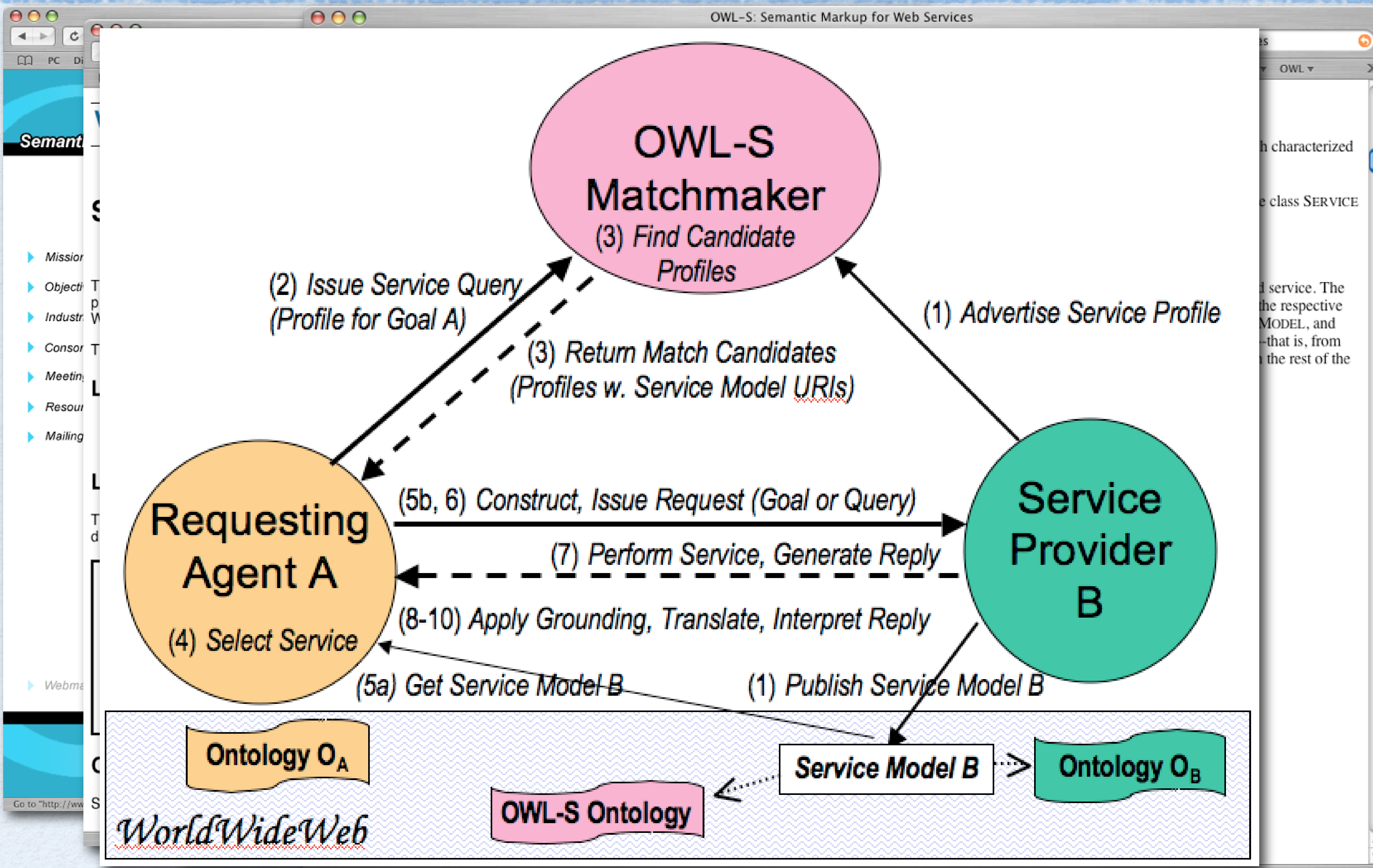

Semantics in SOA

PROBLEM SOLVED!!!

>>> ONTOLOGIES <<<

SAVED THE DAY

AGAIN!!!

REALLY???

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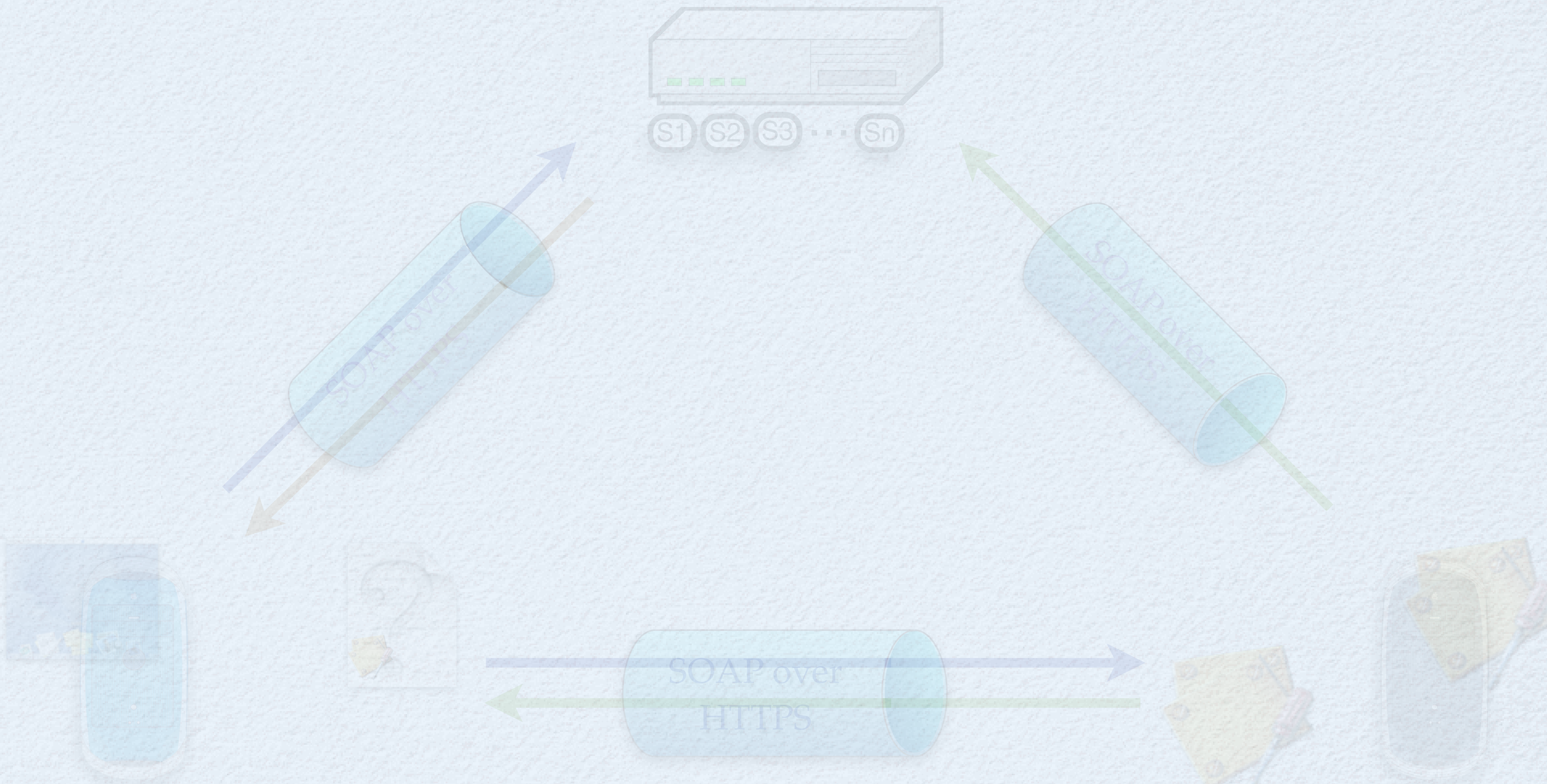
Why Uncertainty in SOA?



Why Uncertainty in SOA?

- Finding and binding processes
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  - Exact translation of terms may not be possible
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CAN BE

PROBLEM SOLVED!!!

PROBABILISTIC

>>> ONTOLOGIES <<<

CAN HELP TO

~~SAVED~~ SAVE THE DAY

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;

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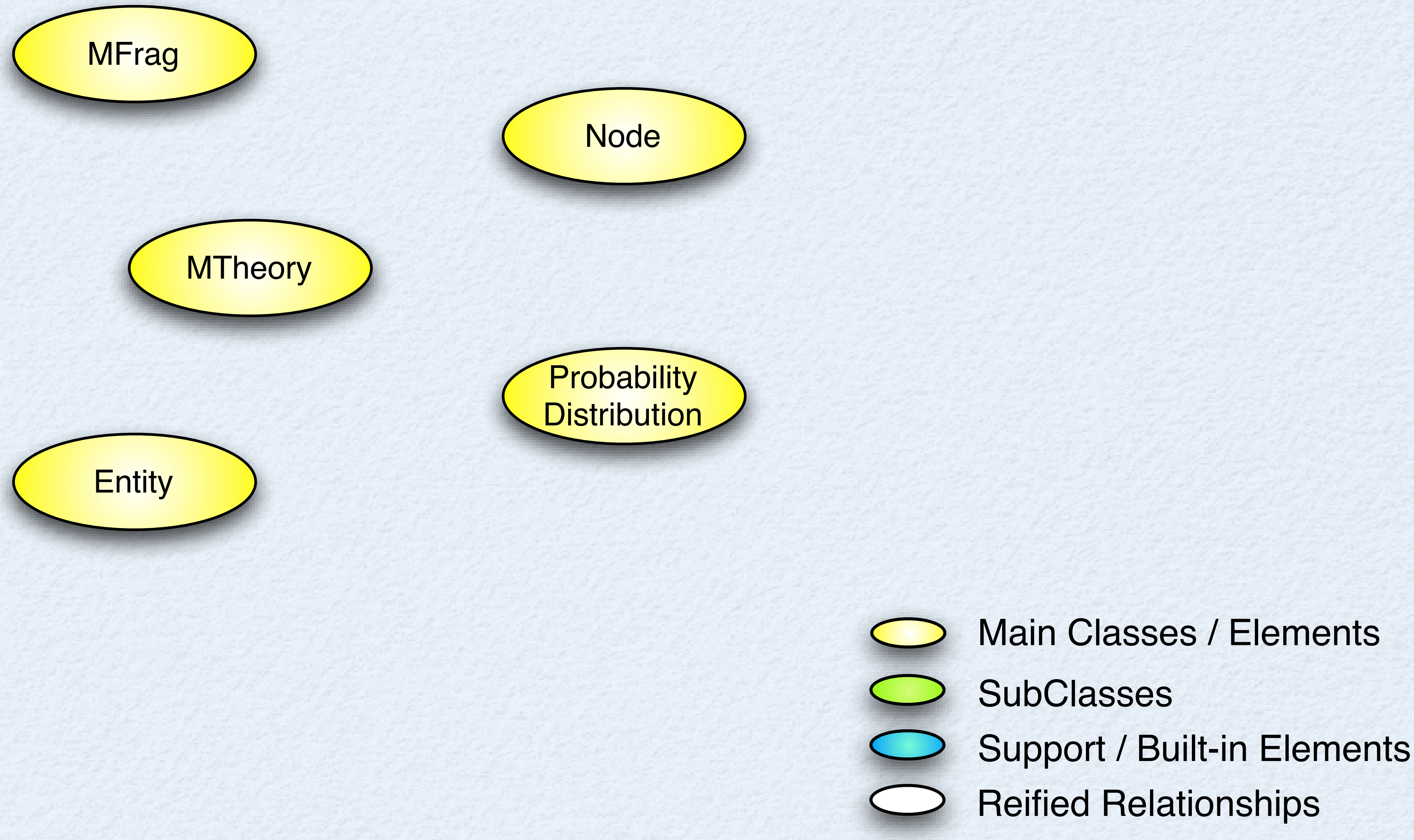
PR-OWL

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

PR-OWL


MFrag
Node
MTheory
Probability Distribution
Entity
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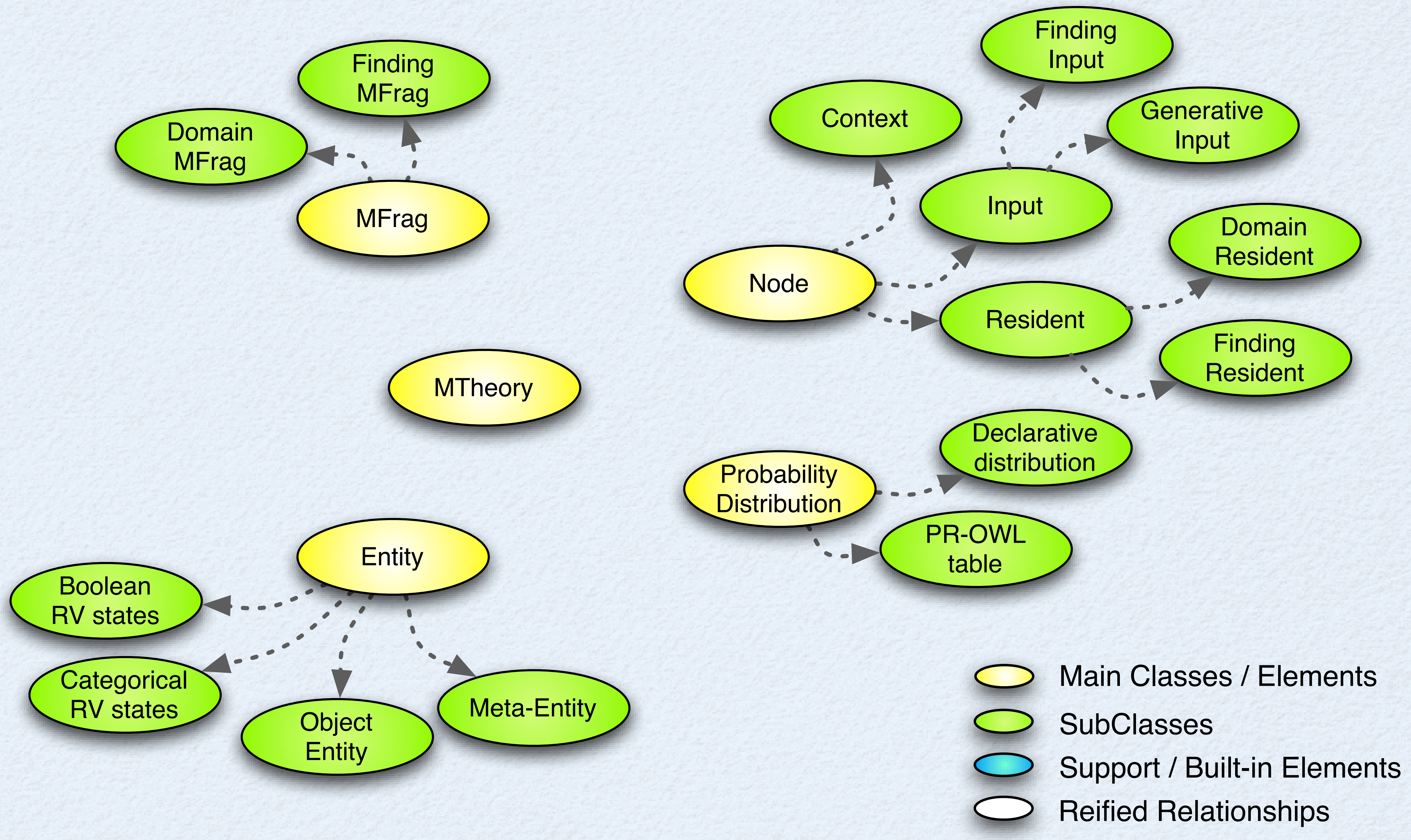
PR-OWL


Finding MFrag
Domain MFrag
MFrag
MTheory
Entity
Boolean RV states
Categorical RV states
Object Entity
Meta-Entity
Context
Finding Input
Generative Input
Input
Domain Resident
Node
Resident
Finding Resident
Declarative distribution
Probability Distribution
PR-OWL table
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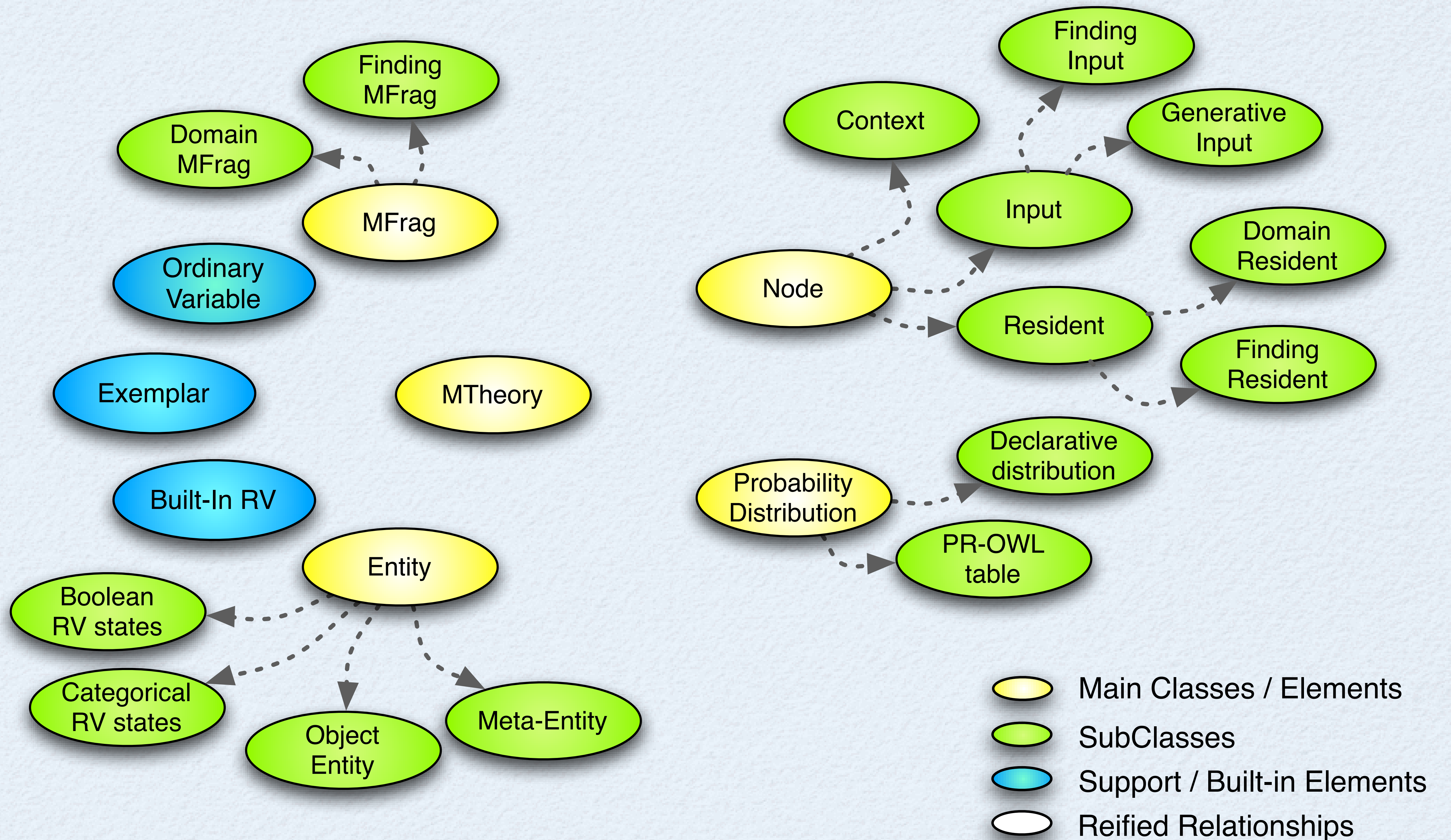
Finding
MFrag
Domain
MFrag
MFrag
Ordinary
Variable
Exemplar
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Entity
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Finding
Input
Context
Generative
Input
Input
Domain
Resident
Node
Resident
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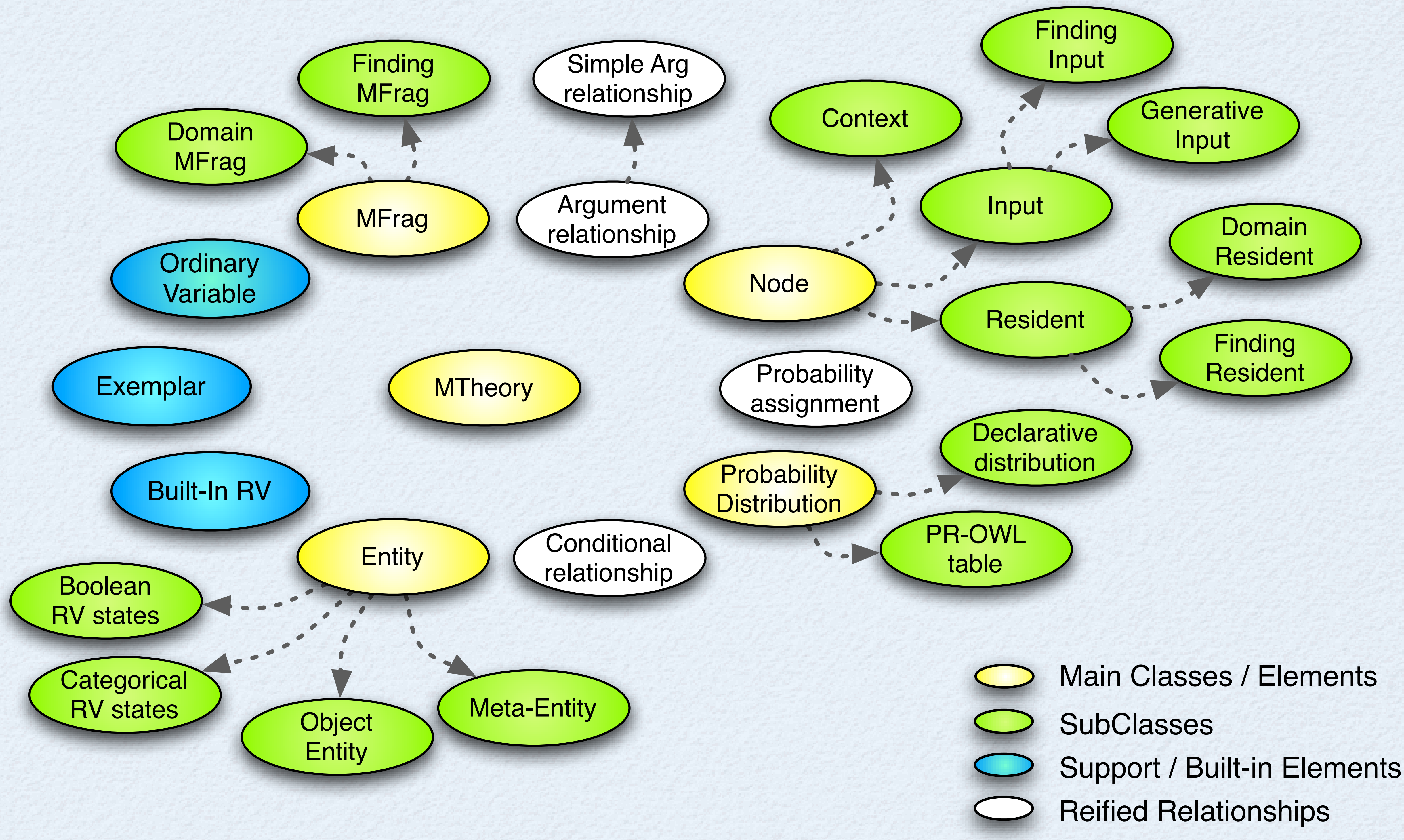
Finding MFrag
Simple Arg relationship
Finding Input
Context
Generative Input
Domain MFrag
MFrag
Argument relationship
Input
Domain Resident
Ordinary Variable
Node
Resident
Finding Resident
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Declarative distribution
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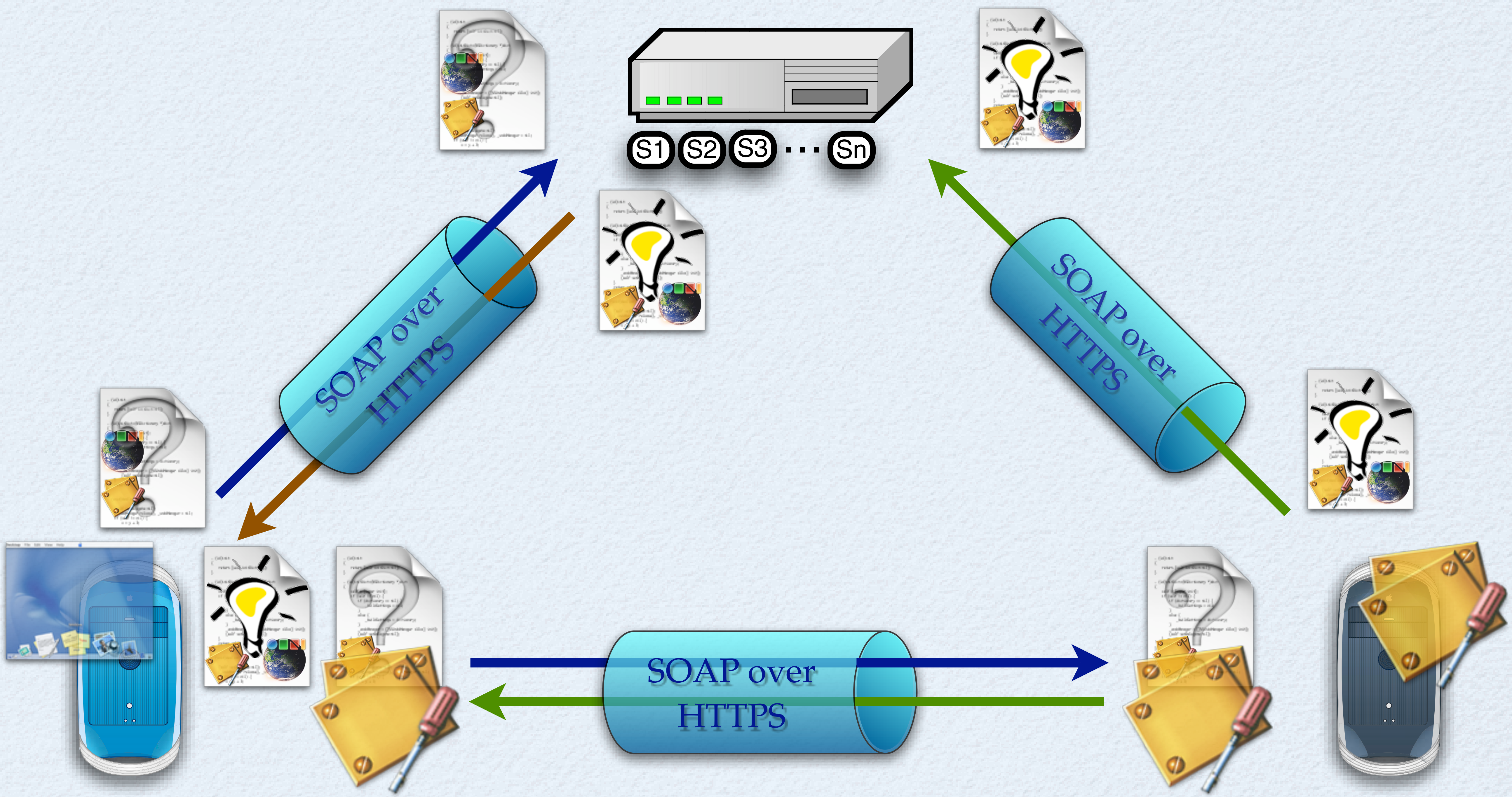


THE EXECUTION CONTEXT

- Security
- Quality of Service
- 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

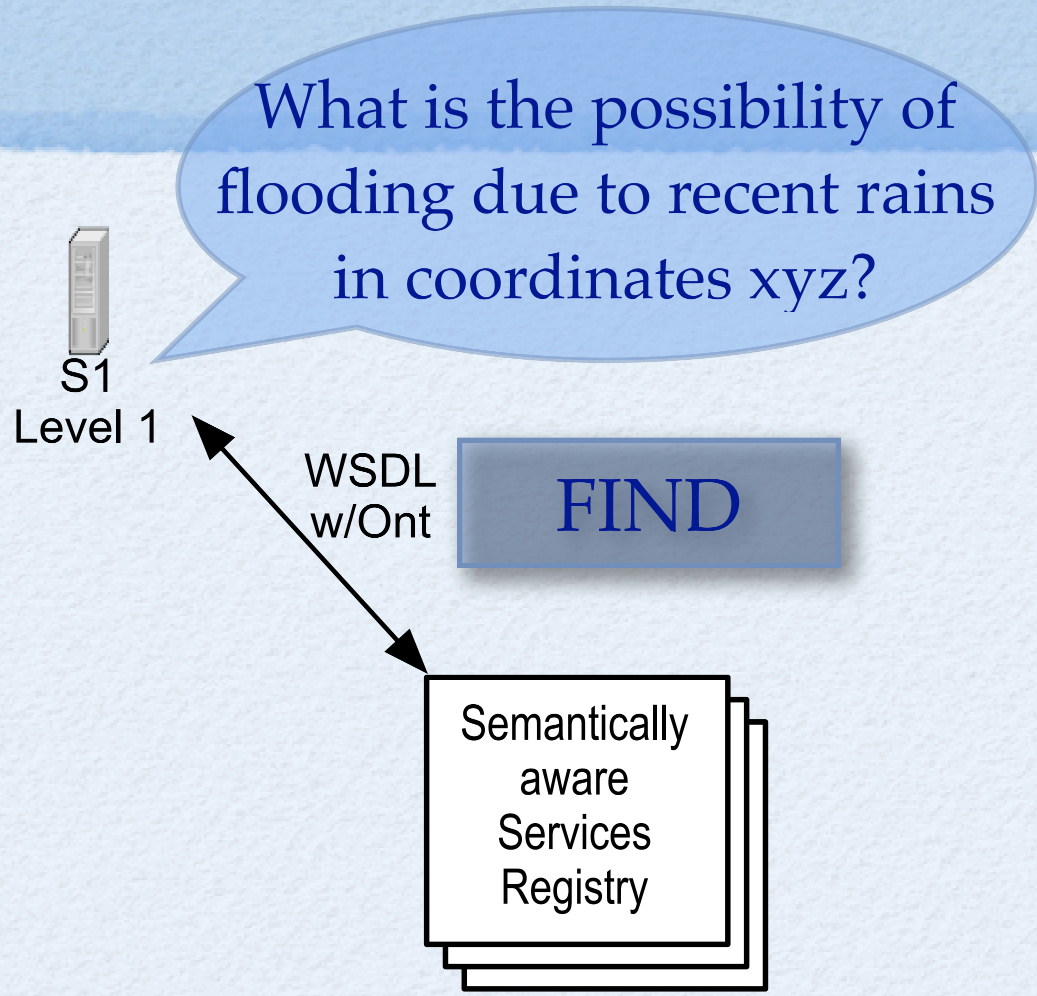
- ★ The above questions do not have simple, universally valid answers
- ★ Deterministic approaches will not suffice to build viable solutions to all of them
- ★ Probabilistic ontologies can help to bridge the gap

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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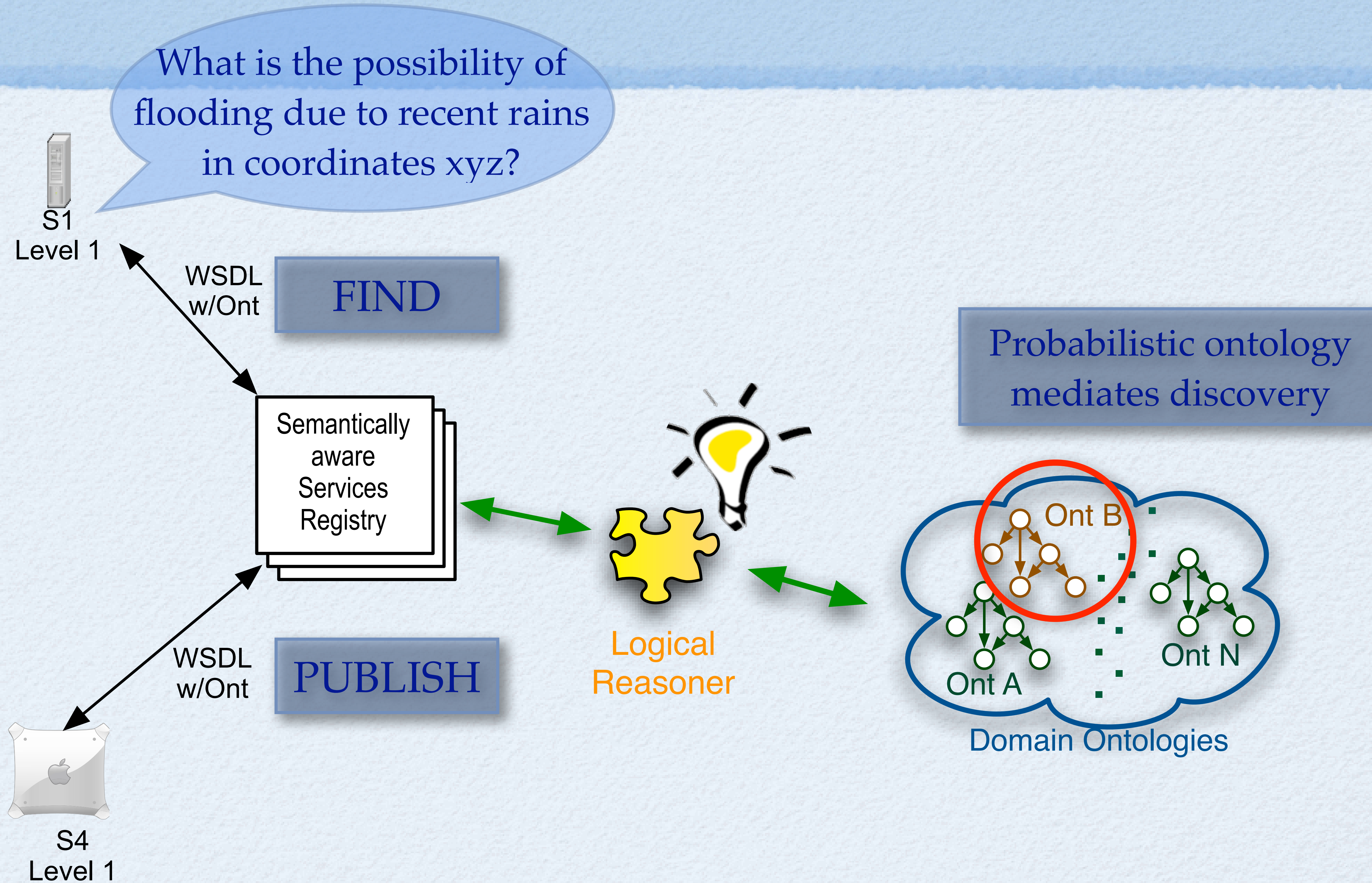

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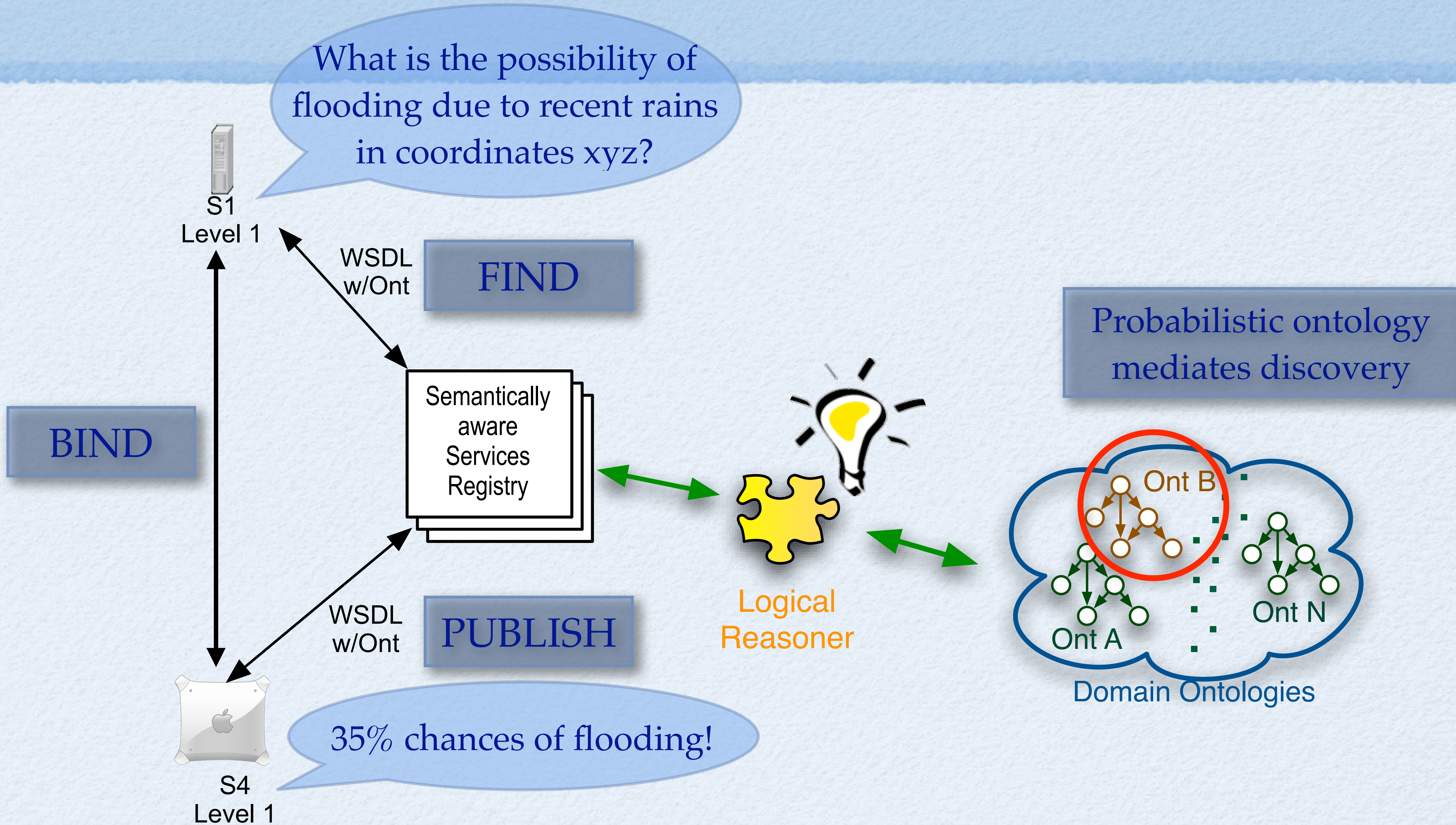

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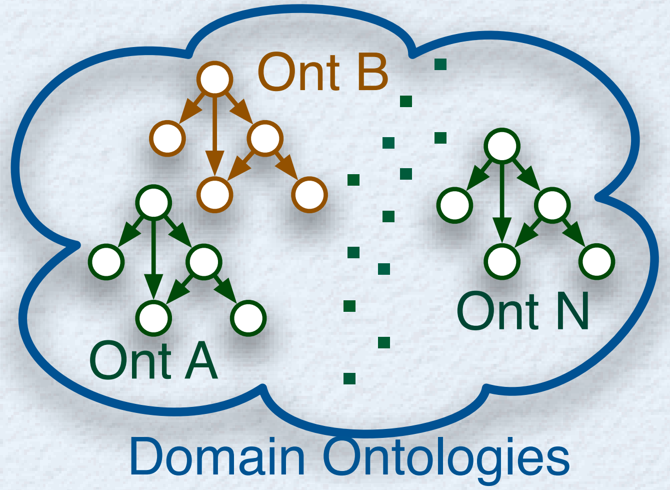
Probabilistic Semantic Mapping



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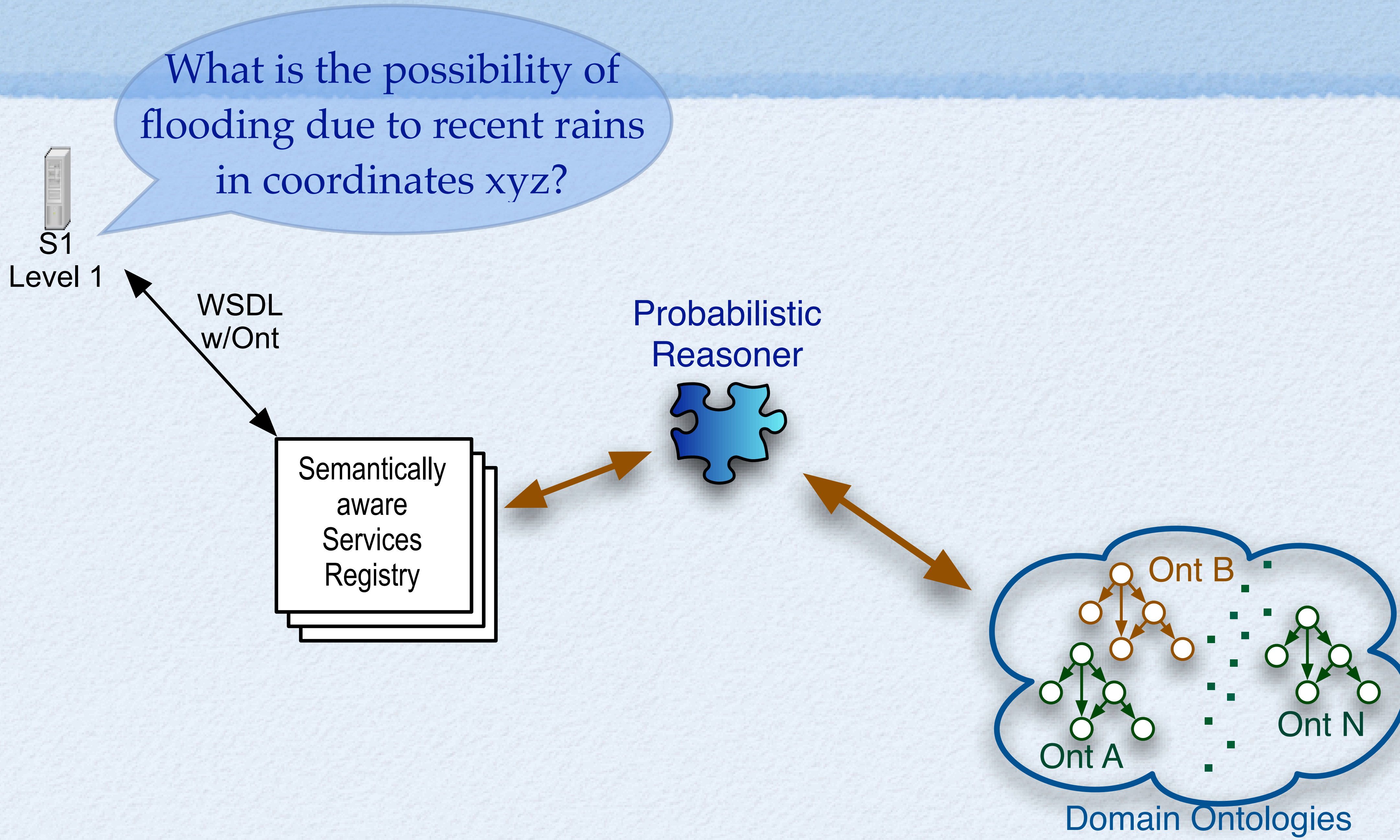

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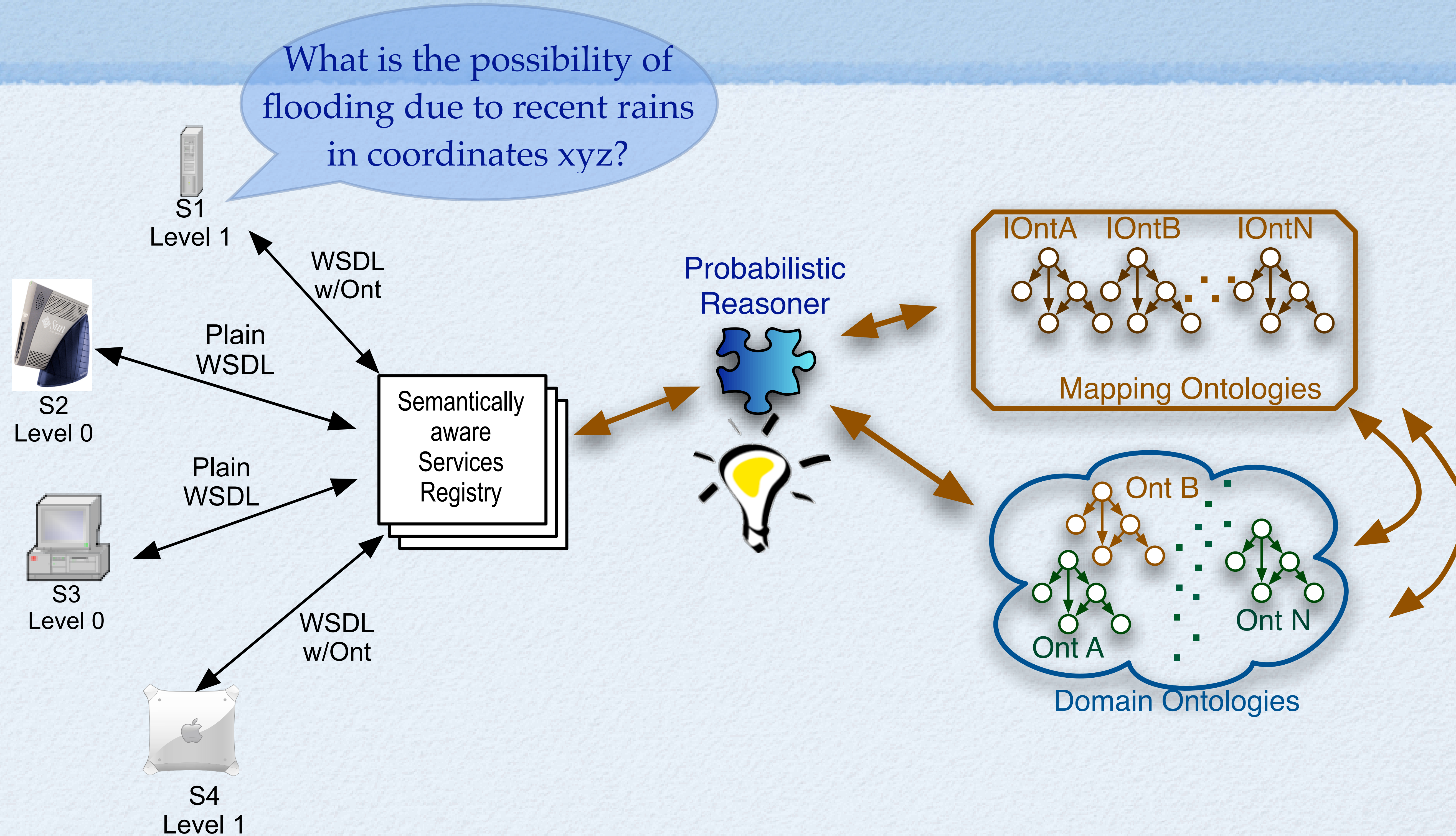

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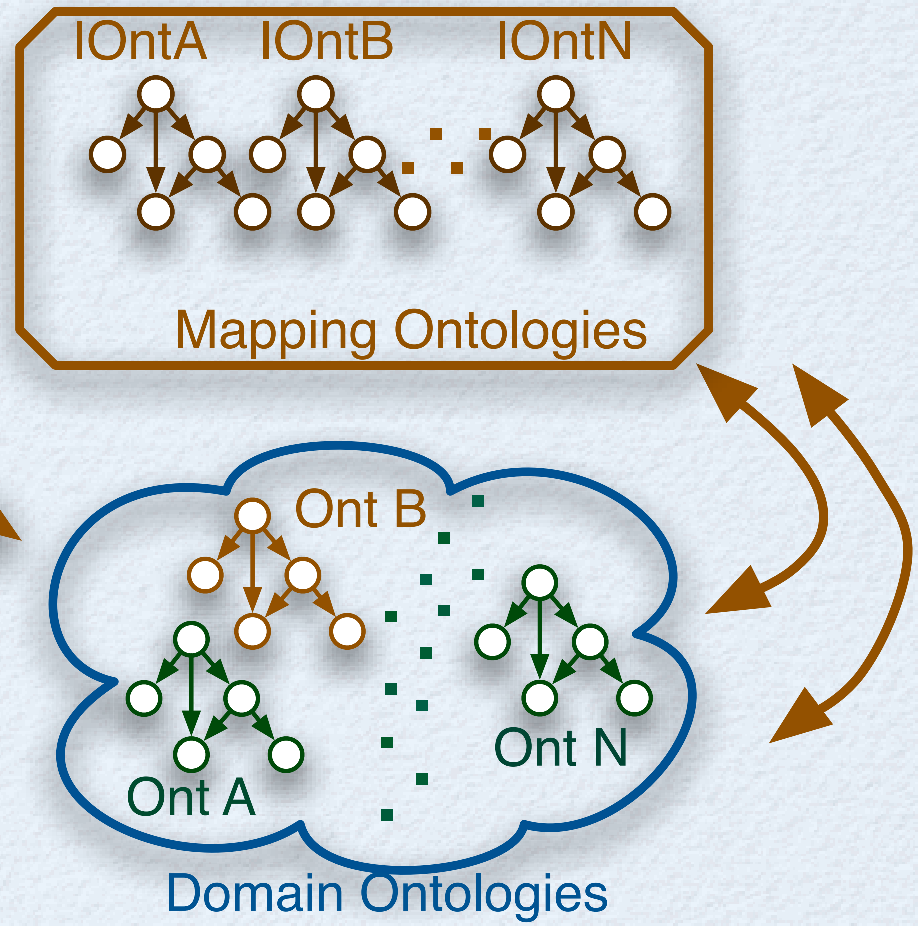
Probabilistic Semantic Mapping

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

- A <u>probabilistic ontology</u> augments a standard ontology with a representation of uncertainty
- A <u>mapping ontology</u> represents mapping of terms between domain ontologies



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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:

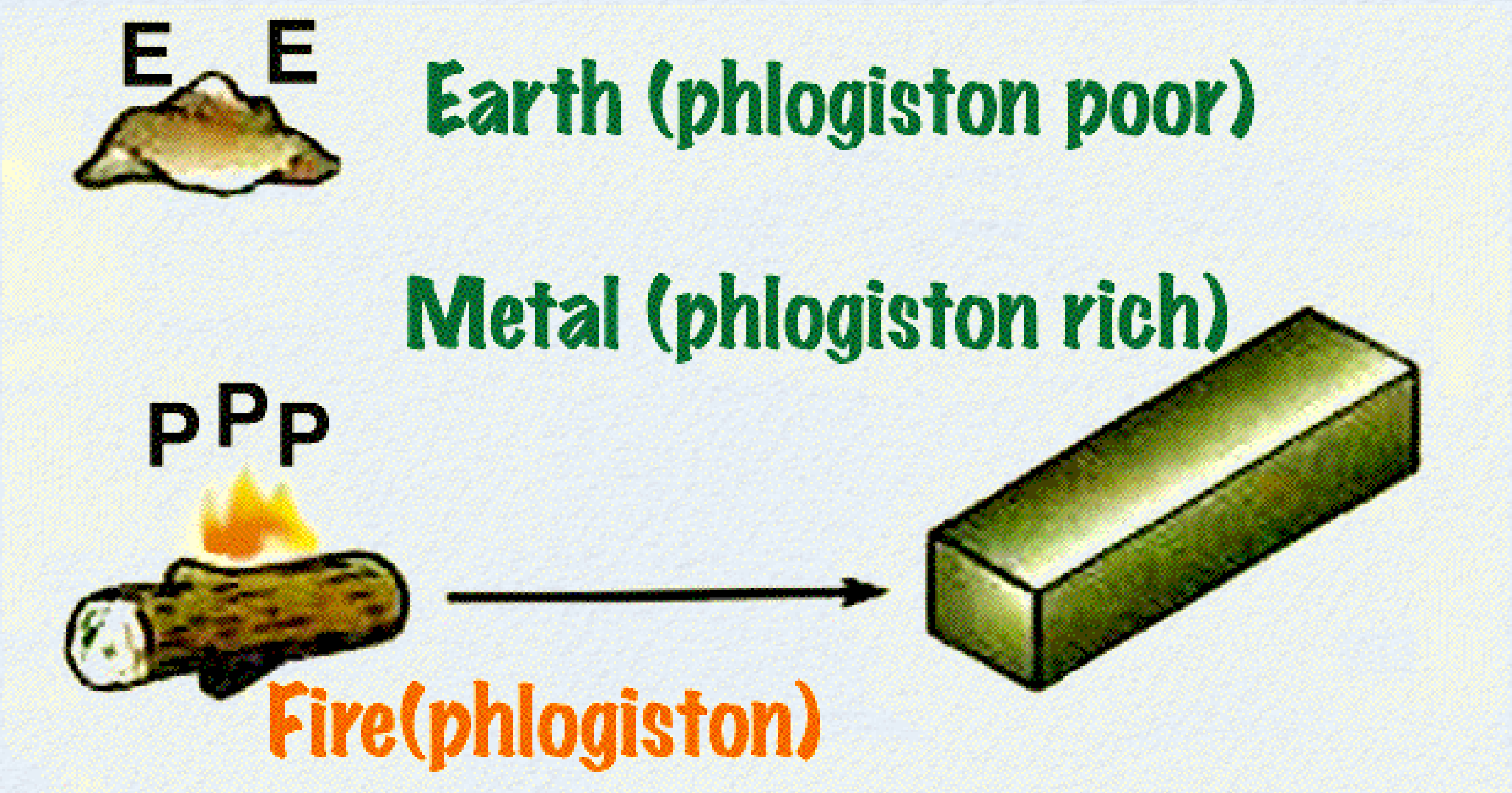
Probability as a natural phenomenon

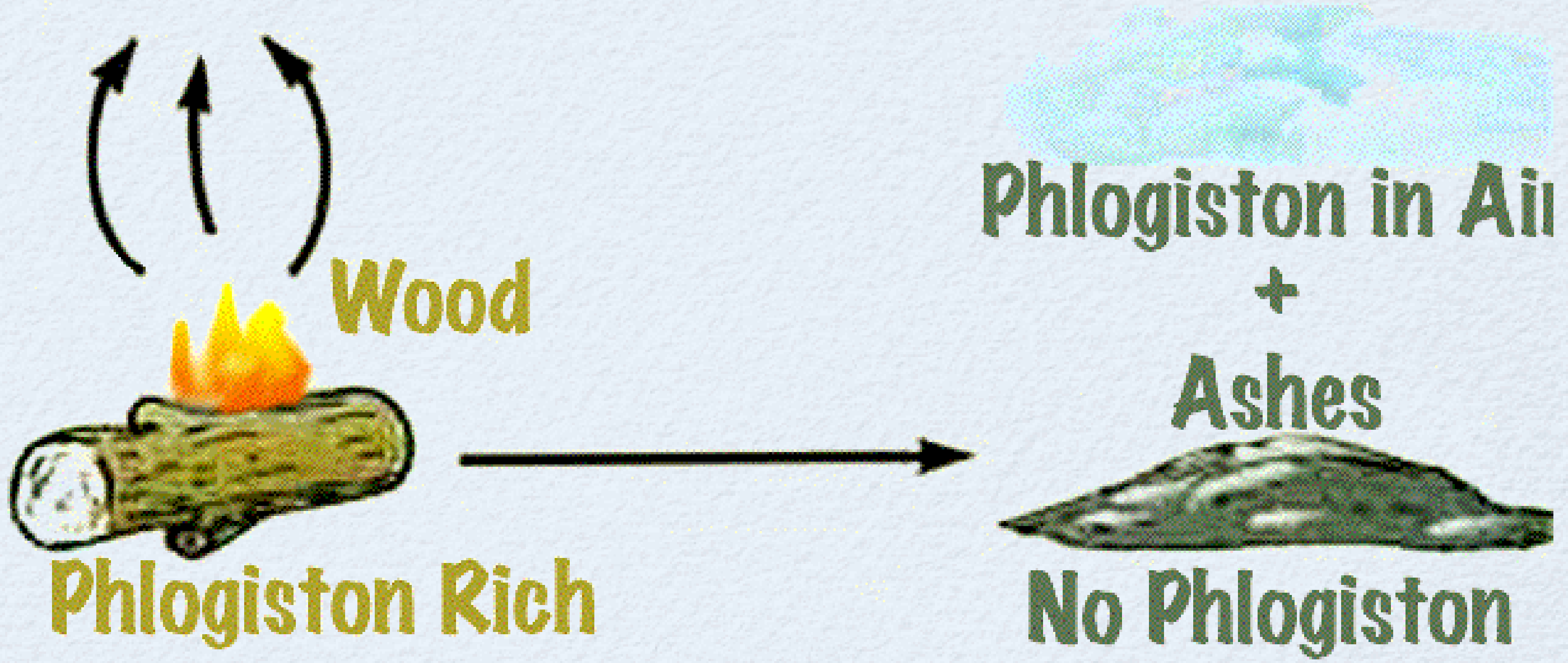
vs.

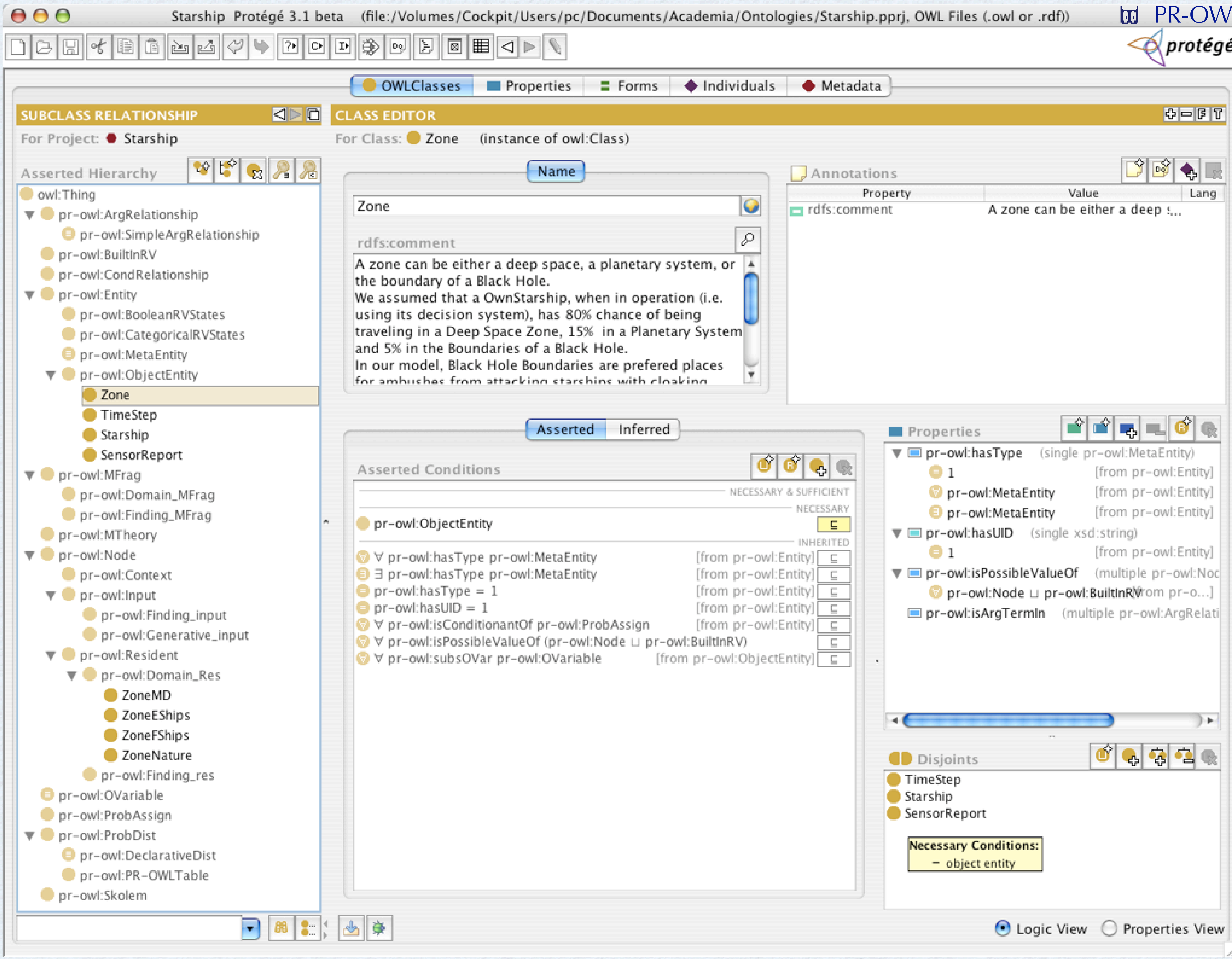
Probability as an epistemic phenomenon

THE "PHLOGINSTON ONTOLOGY"

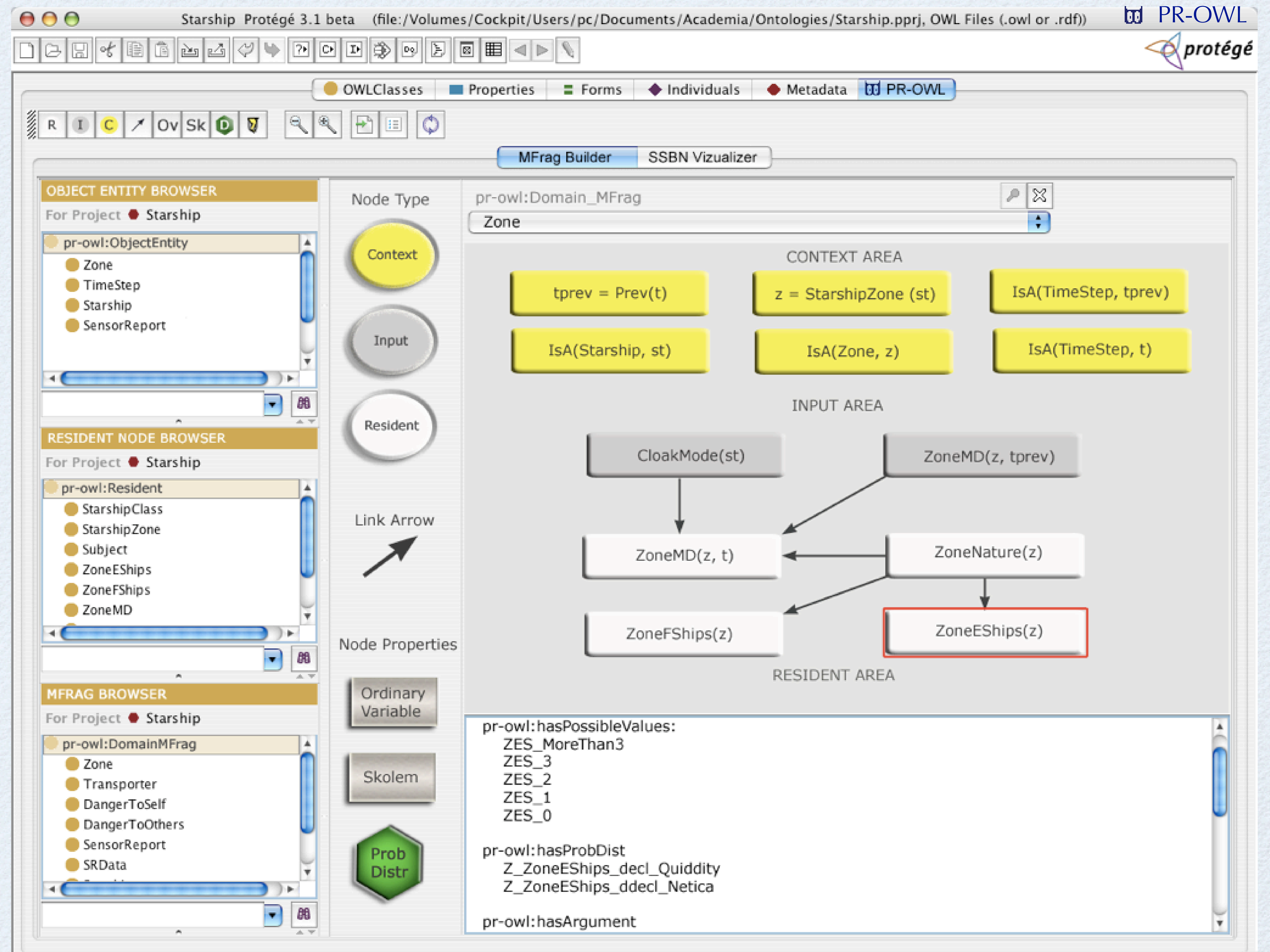
The "Phloginston Ontology"







Starship Protégé 3.1 beta (file:/Volumes/Cockpit/Users/pc/Documents/Academia/Ontologies/Starship.pprj, OWL Files (.owl or .rdf))
PR-OWL
protégé
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:MFrag
pr-owl:Domain_MFrag
pr-owl:Finding_MFrag
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 prefered places for ambushes from attacking starships with cloaking
Annotations
Property
Value
Lang
rdfs:comment
A zone can be either a deep s...
Asserted
Inferred
Asserted Conditions
NECESSARY & SUFFICIENT
NECESSARY
pr-owl:ObjectEntity
INHERITED
∀ pr-owl:hasType pr-owl:MetaEntity [from pr-owl:Entity]
∃ pr-owl:hasType pr-owl:MetaEntity [from pr-owl:Entity]
pr-owl:hasType = 1 [from pr-owl:Entity]
pr-owl:hasUID = 1 [from pr-owl:Entity]
∀ pr-owl:isConditionantOf pr-owl:ProbAssign [from pr-owl:Entity]
∀ pr-owl:isPossibleValueOf (pr-owl:Node ⊔ pr-owl:BuiltInRV)
∀ pr-owl:subsOVar pr-owl:OVariable [from pr-owl:ObjectEntity]
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:Noc
pr-owl:Node ⊔ pr-owl:BuiltInRV
pr-owl:isArgTermIn (multiple pr-owl:ArgRelati
Disjoints
TimeStep
Starship
SensorReport
Necessary Conditions:
− object entity
Logic View
Properties View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PR-OWL
protégé
OWLClasses
Properties
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Individuals
Metadata
PR-OWL
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
CONTEXT AREA
tprev = Prev(t)
z = StarshipZone (st)
IsA(TimeStep, tprev)
IsA(Starship, st)
IsA(Zone, z)
IsA(TimeStep, t)
INPUT AREA
CloakMode(st)
ZoneMD(z, tprev)
ZoneMD(z, t)
ZoneNature(z)
ZoneFShips(z)
ZoneEShips(z)
RESIDENT AREA
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

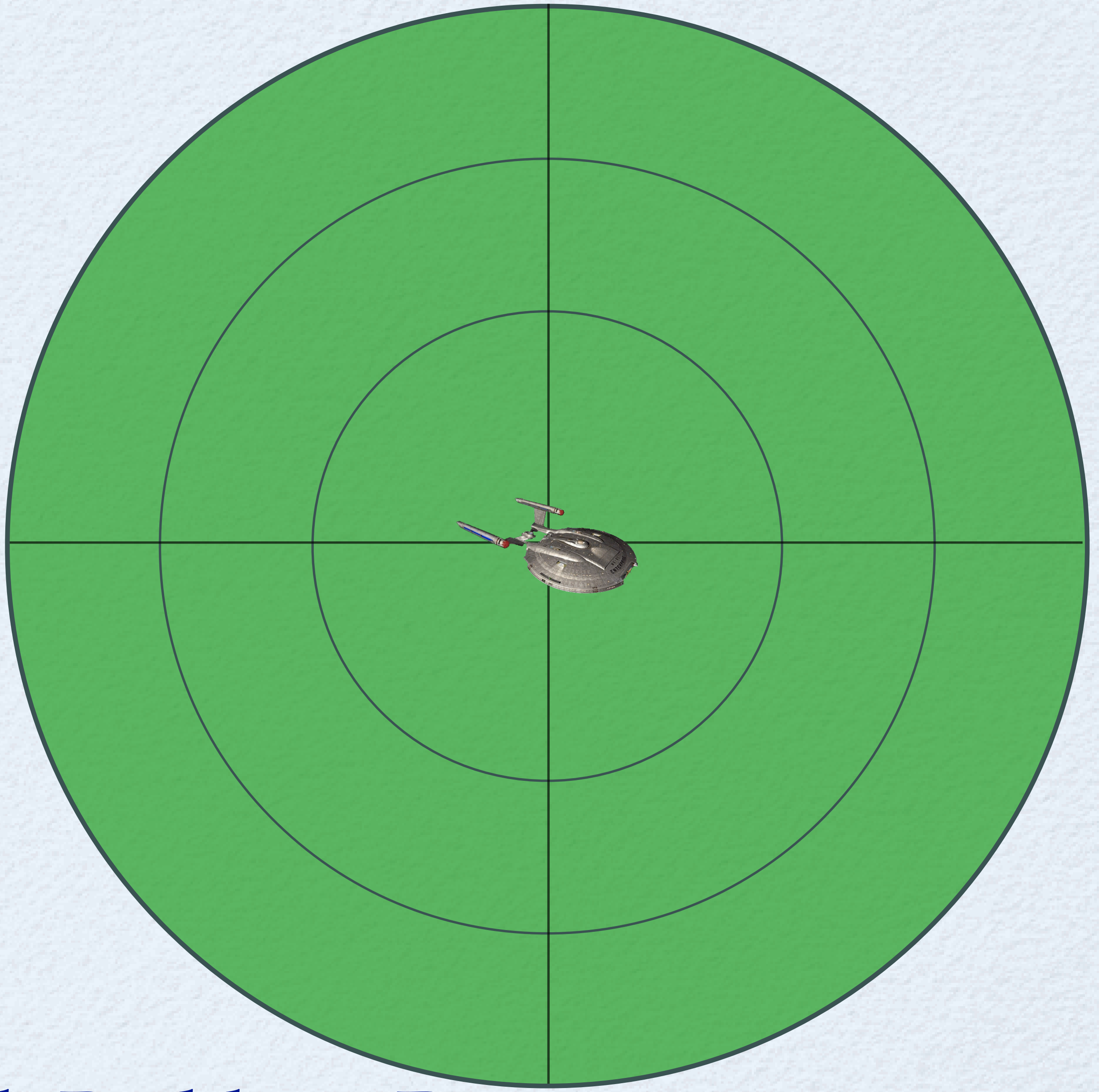
Why Bayes?

- ★ Requirement: reason in the presence of uncertainty about...
  - Input data
  - Existence of relationships among entities
  - 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?

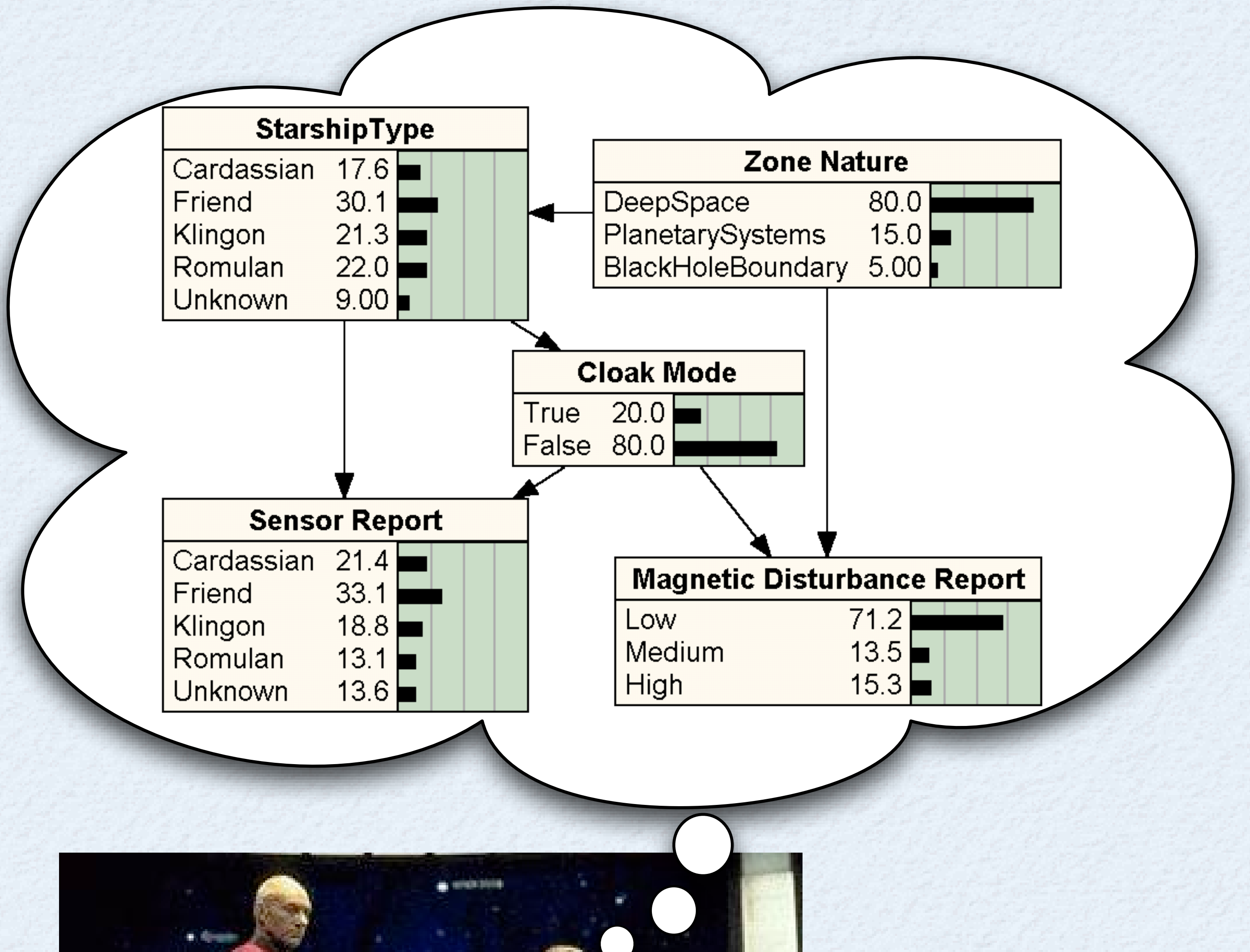
Why BNs are unfit for POs?

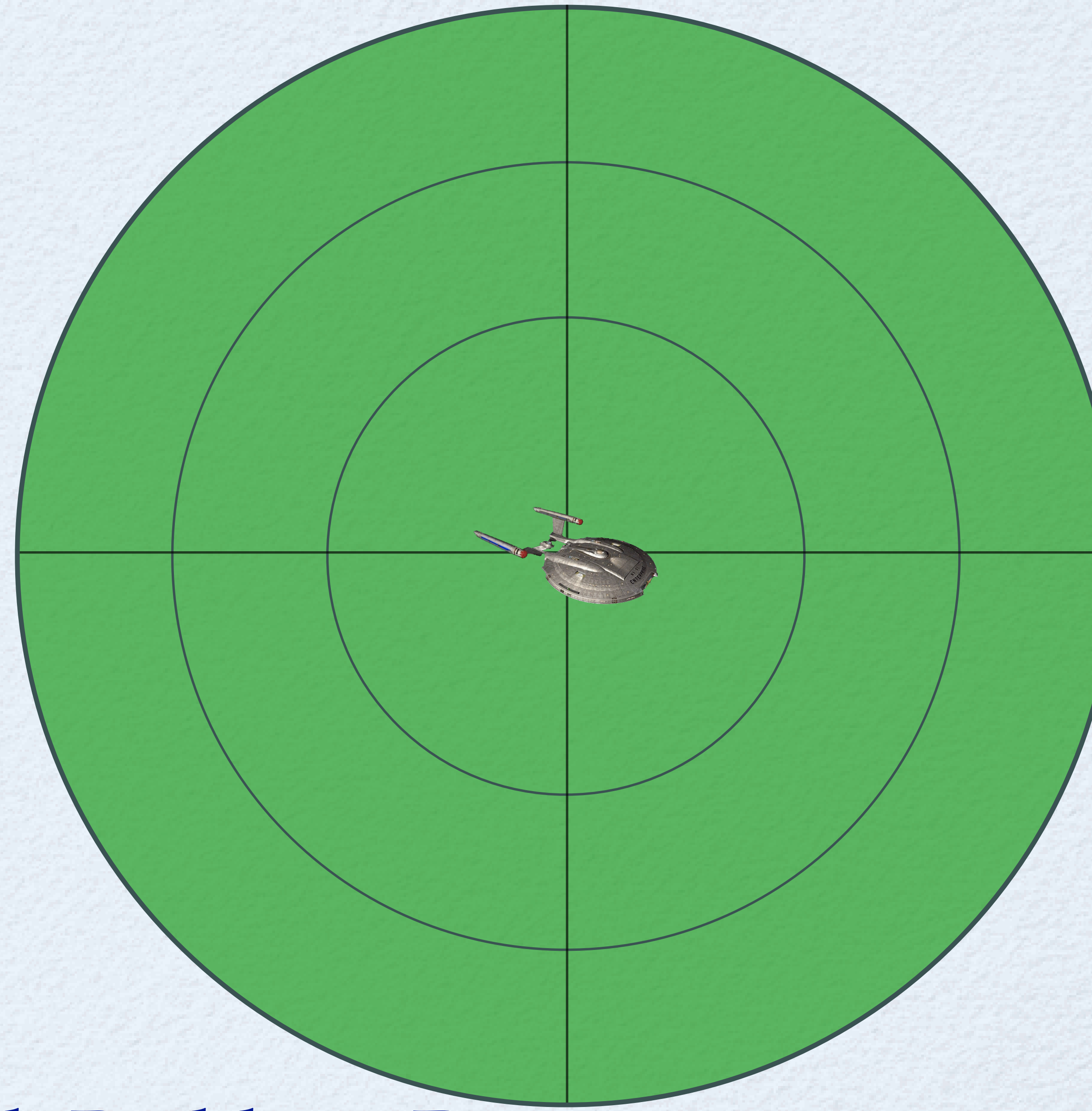
<u>Bayesian Reasoning</u>: Update prior beliefs as evidence accrues. All new data can be considered.



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

Why BNs are unfit for POs?





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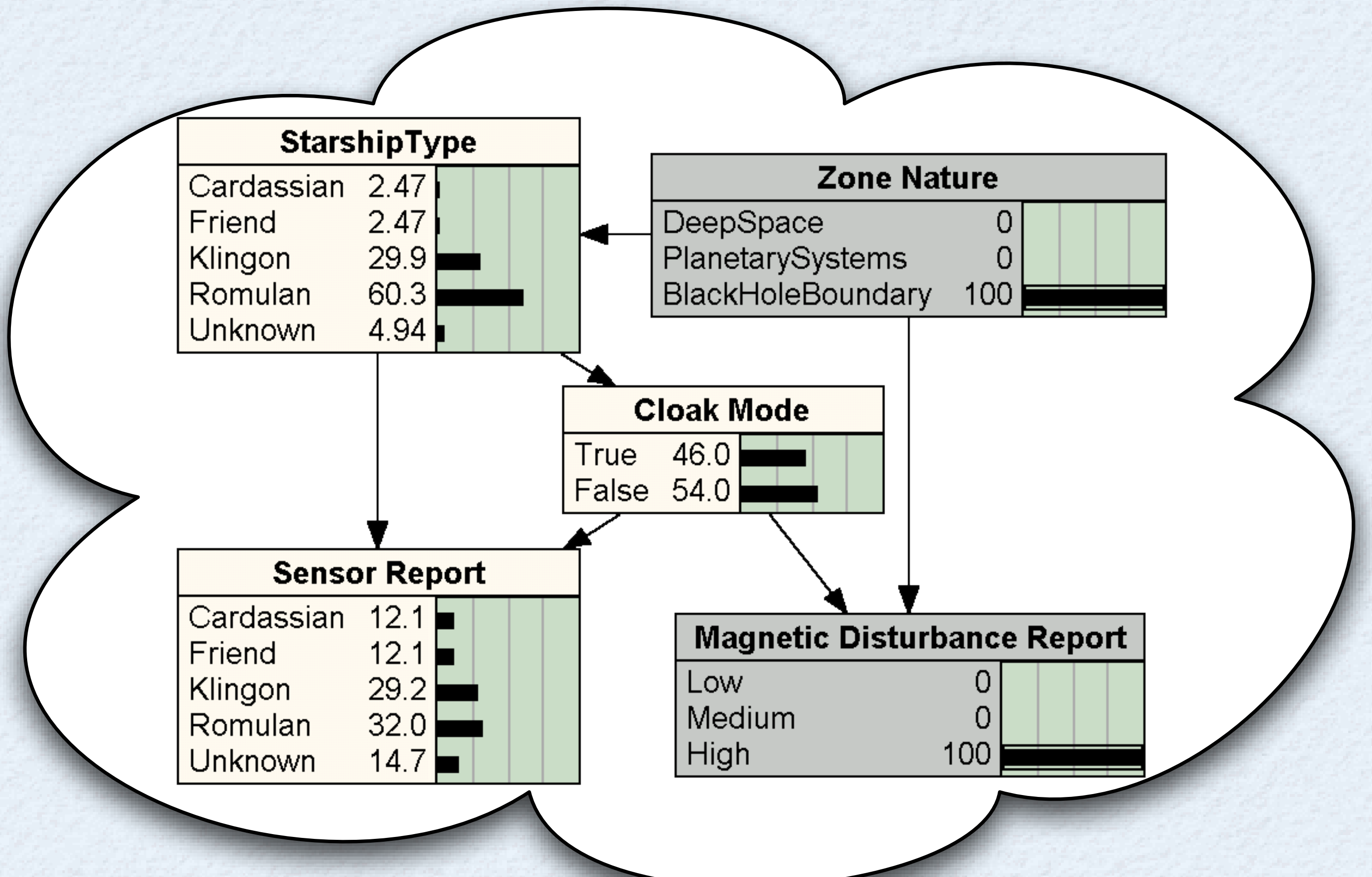

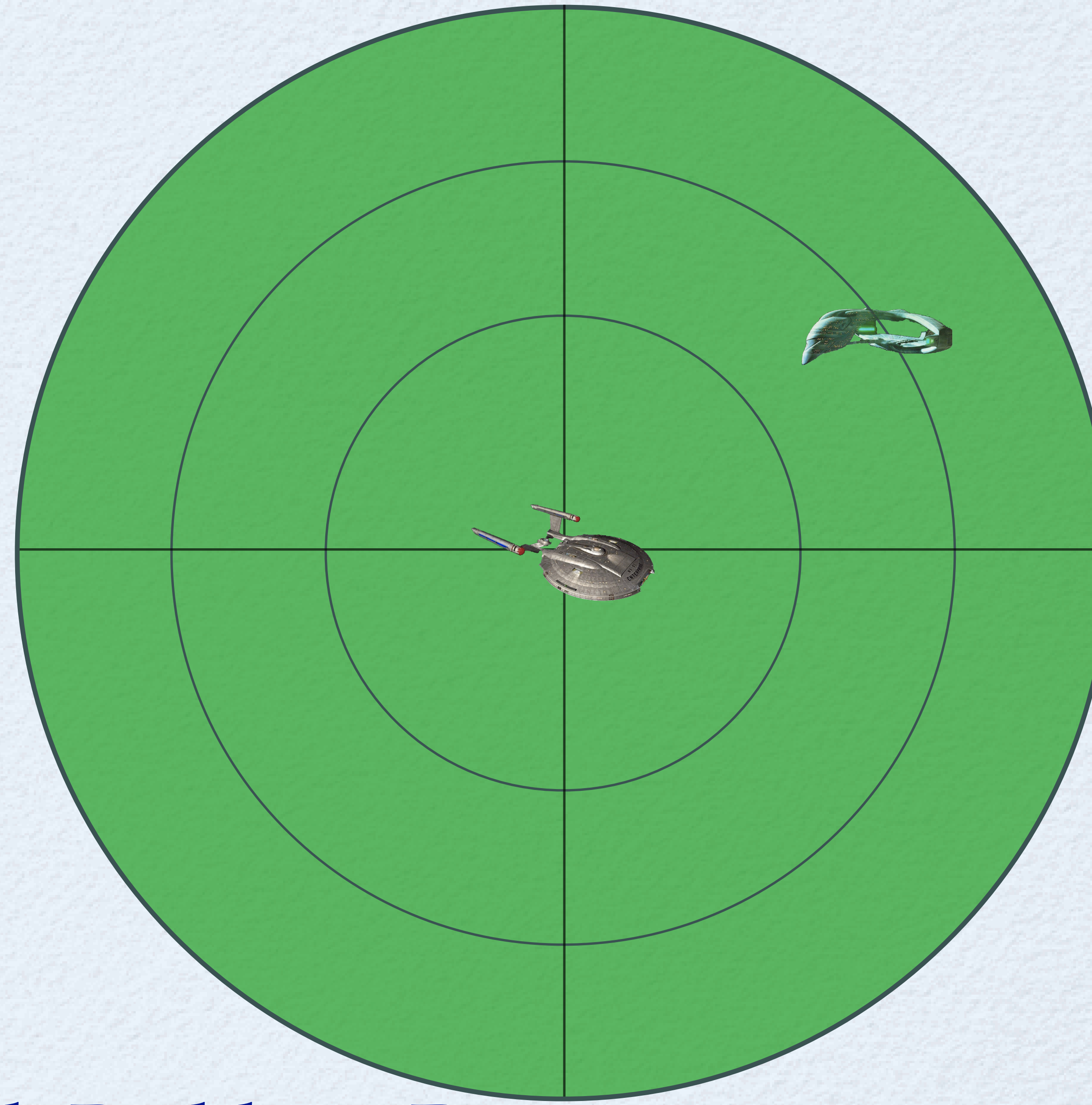

The Star Trek Problem: Discriminating Starships and making decisions with incomplete and uncertain knowledge

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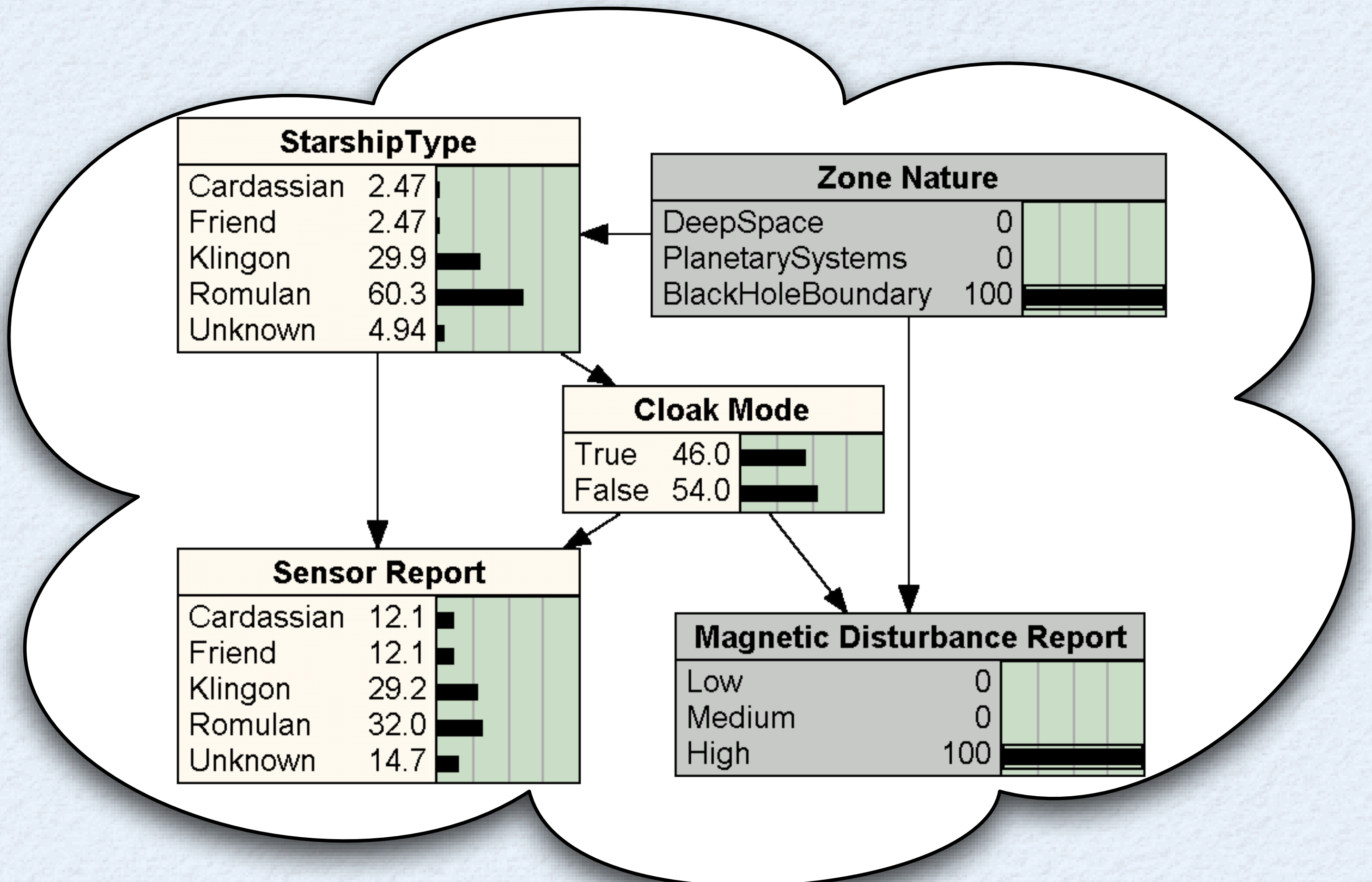

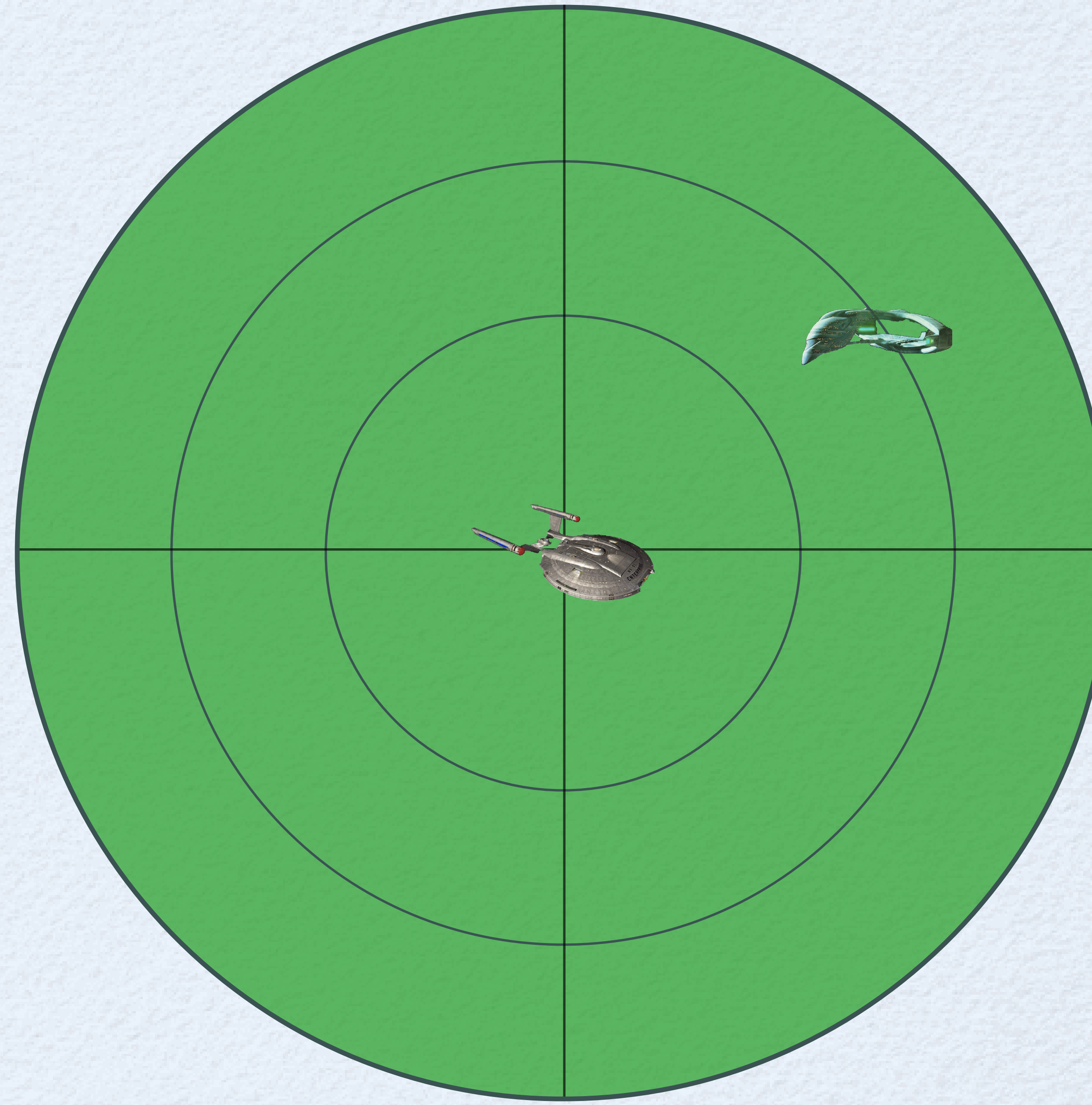

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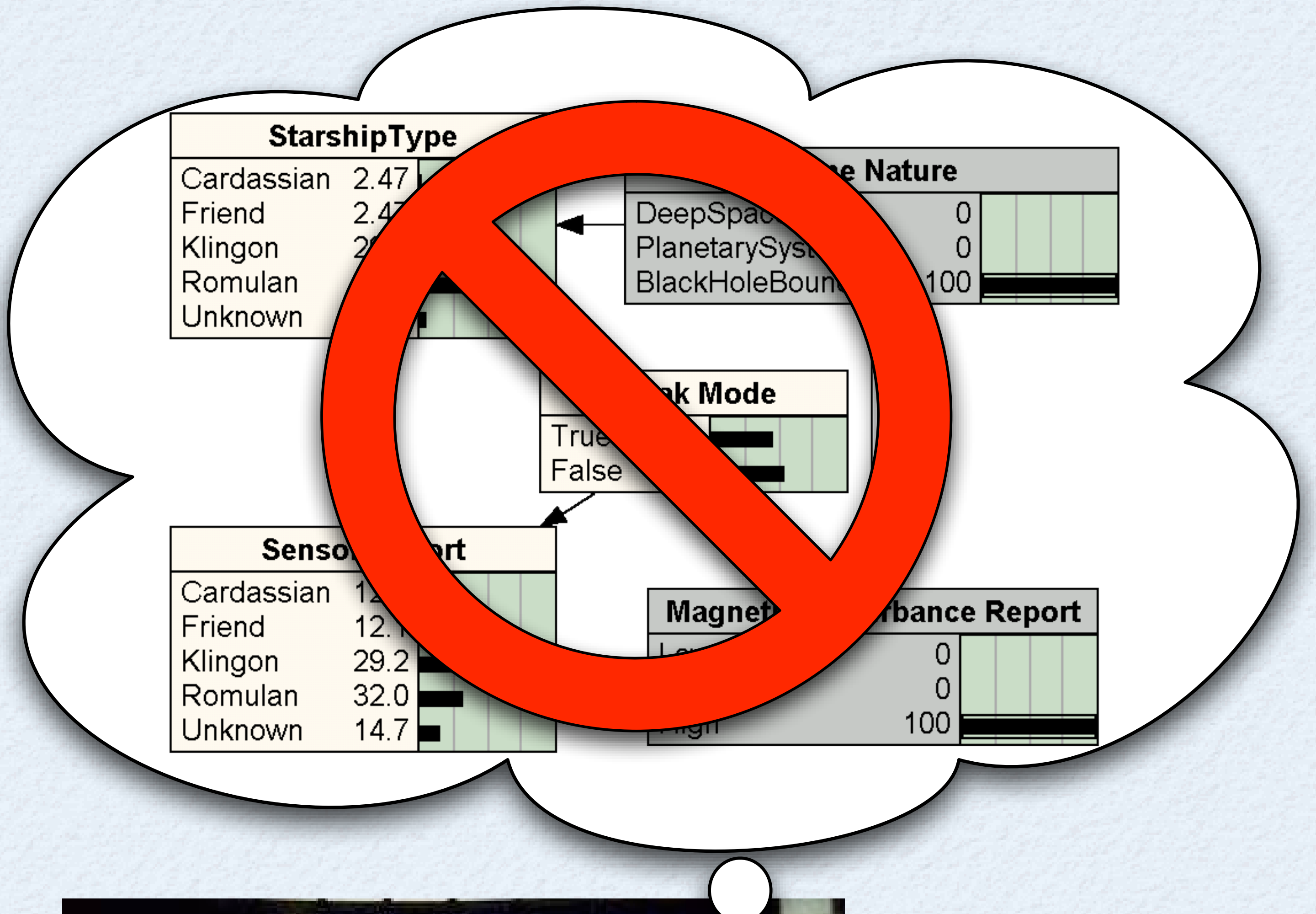
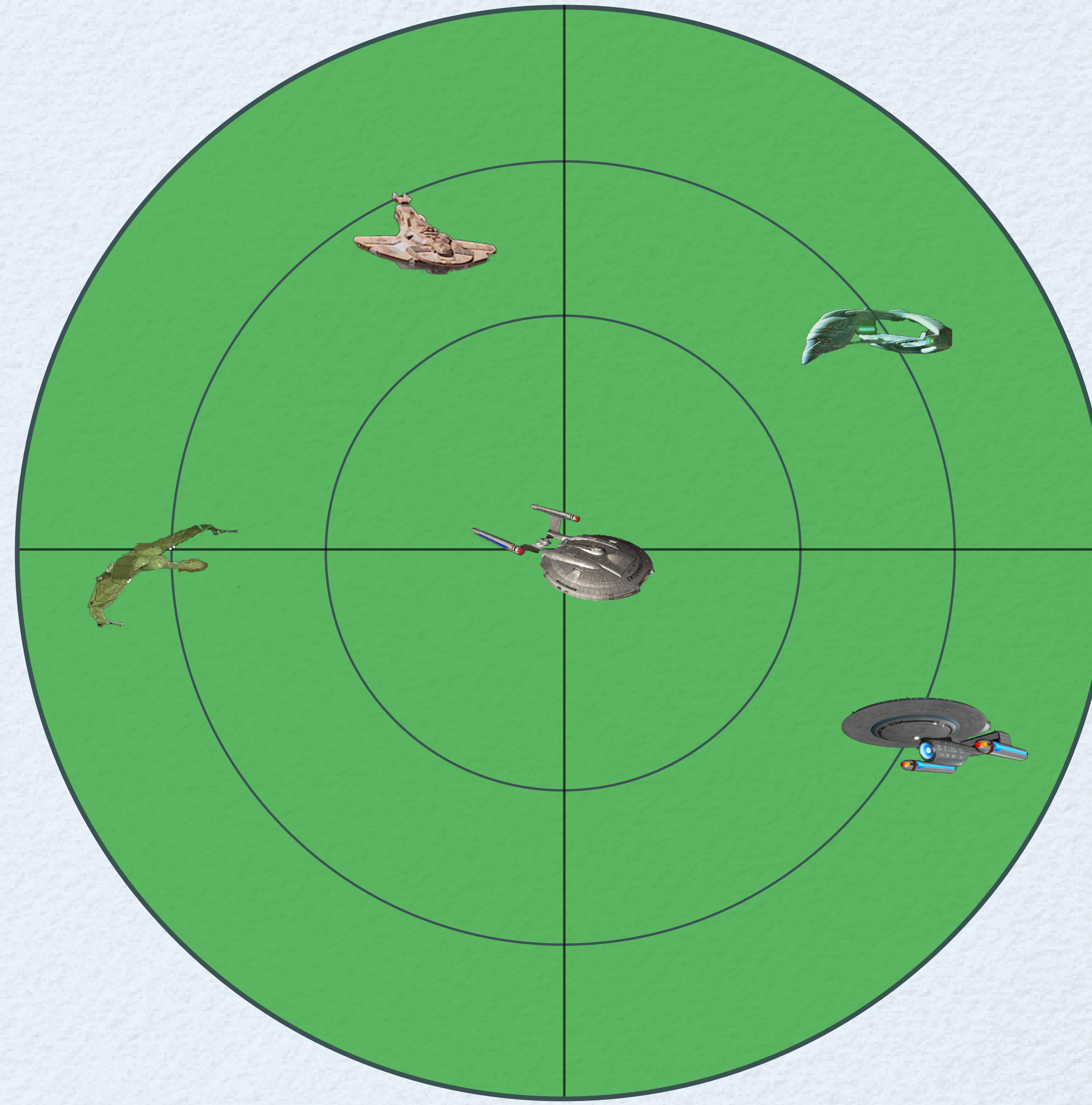
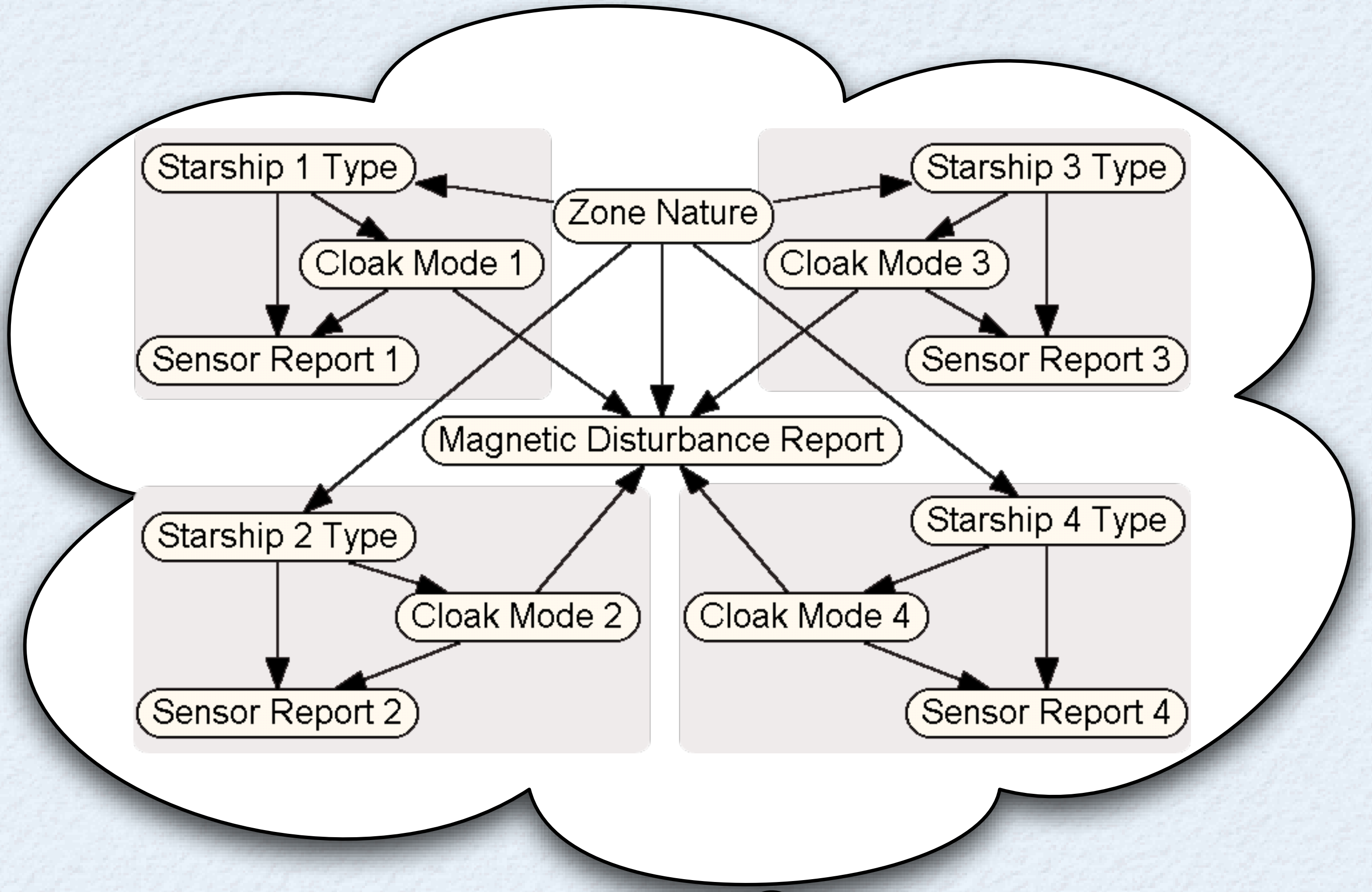
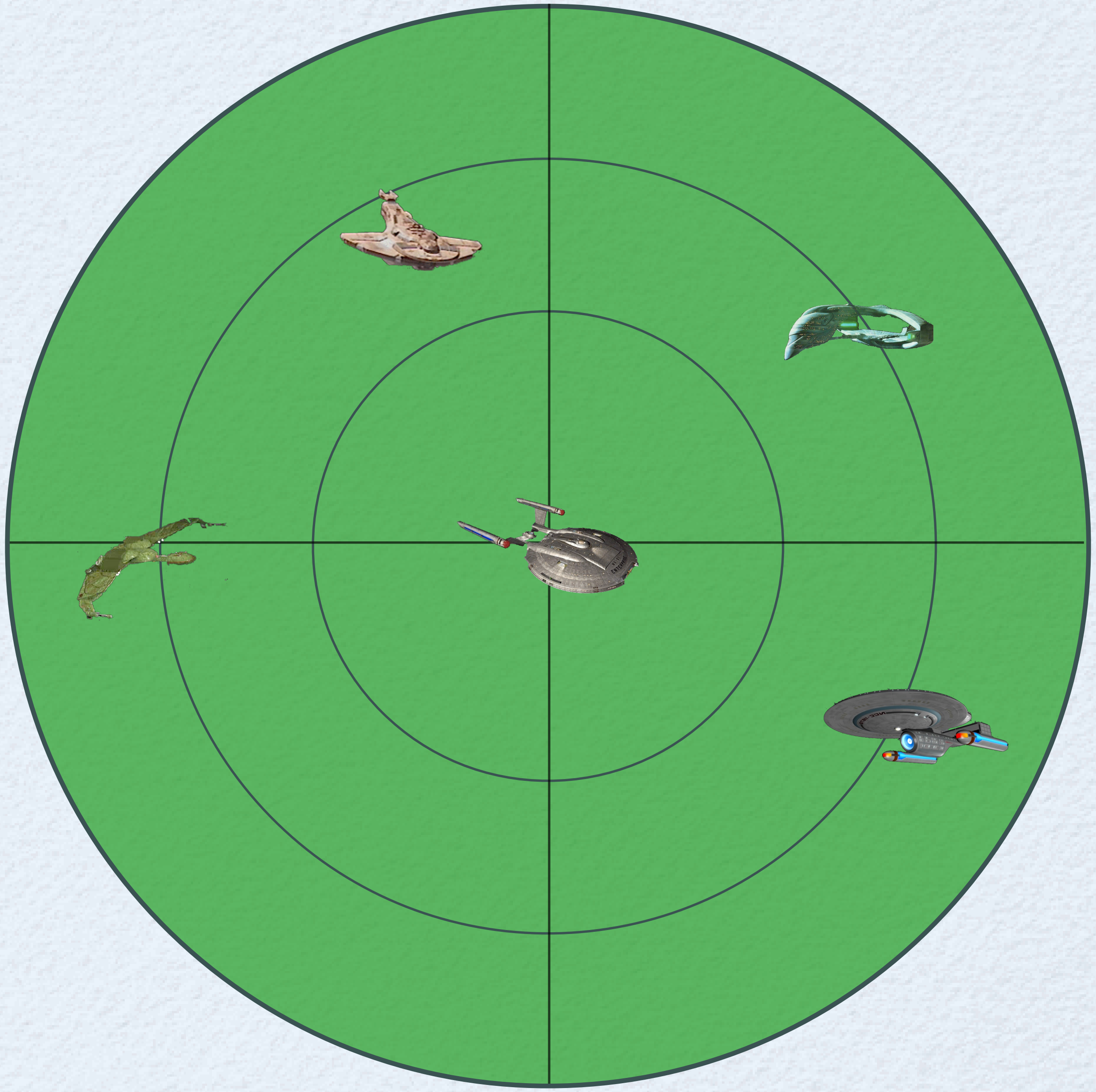




How about multiple starships showing up at the same time? One BN for each situation?

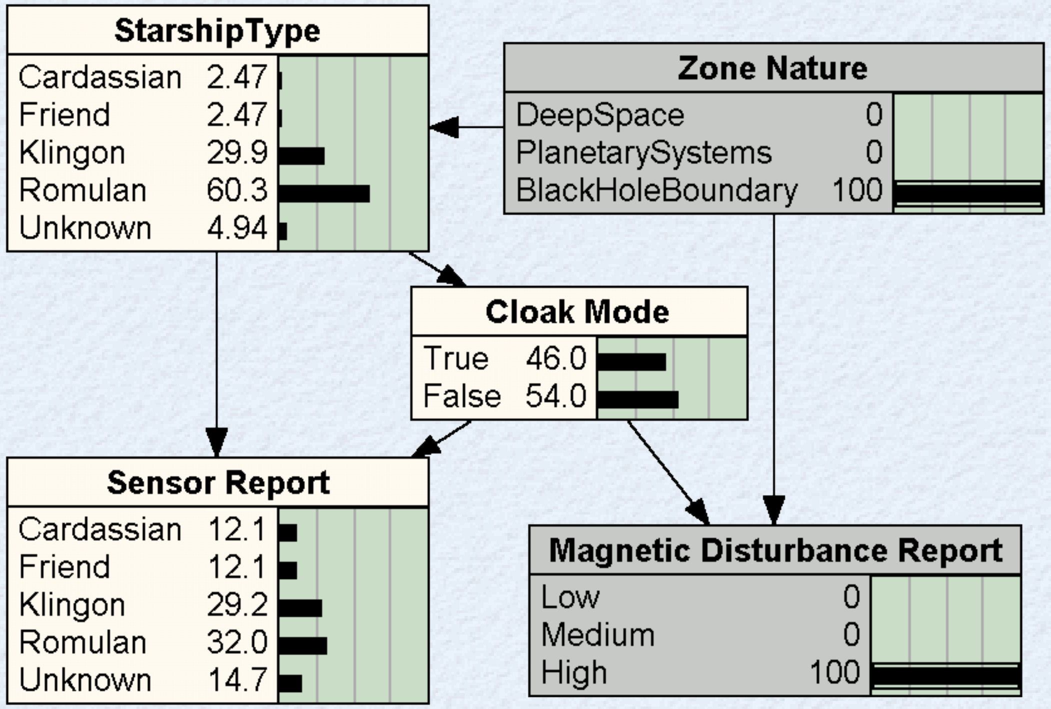
Why BNs are unfit for POs?



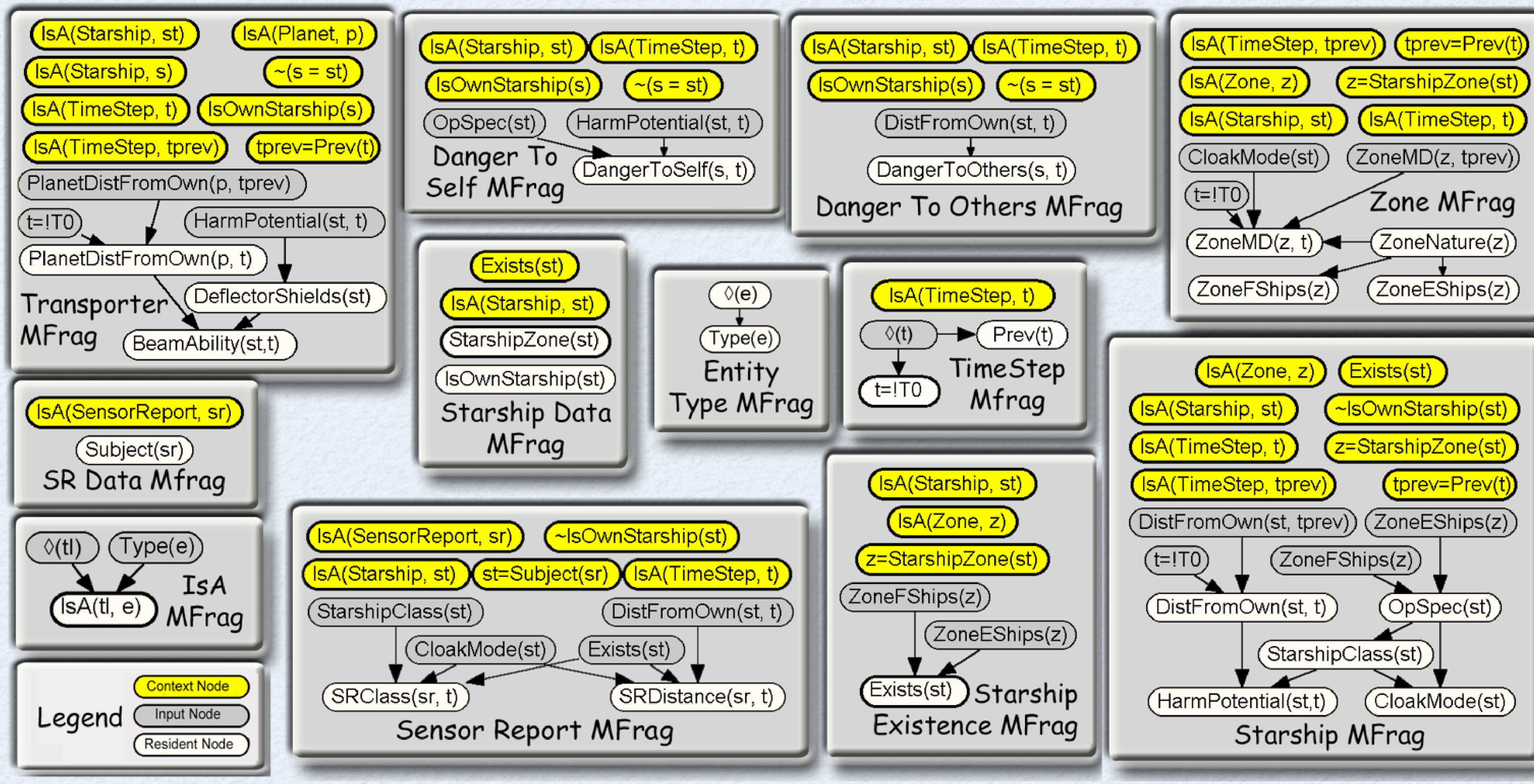


How about multiple starships showing up at the same time? One BN for each situation?

MEBN: FOL Expressiveness



MEBN: FOL Expressiveness



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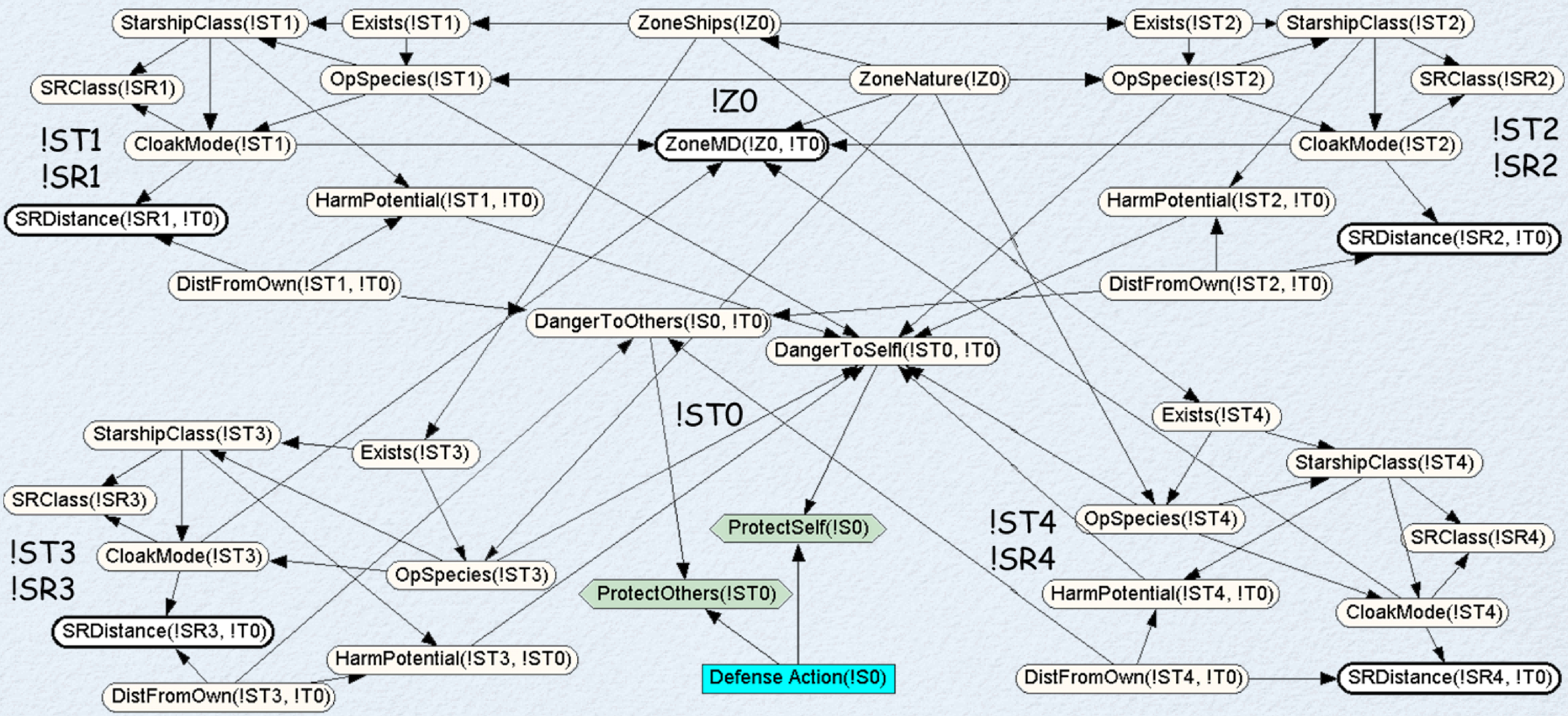

MEBN Fragments

Building blocks that collectively form a model (MTheory)

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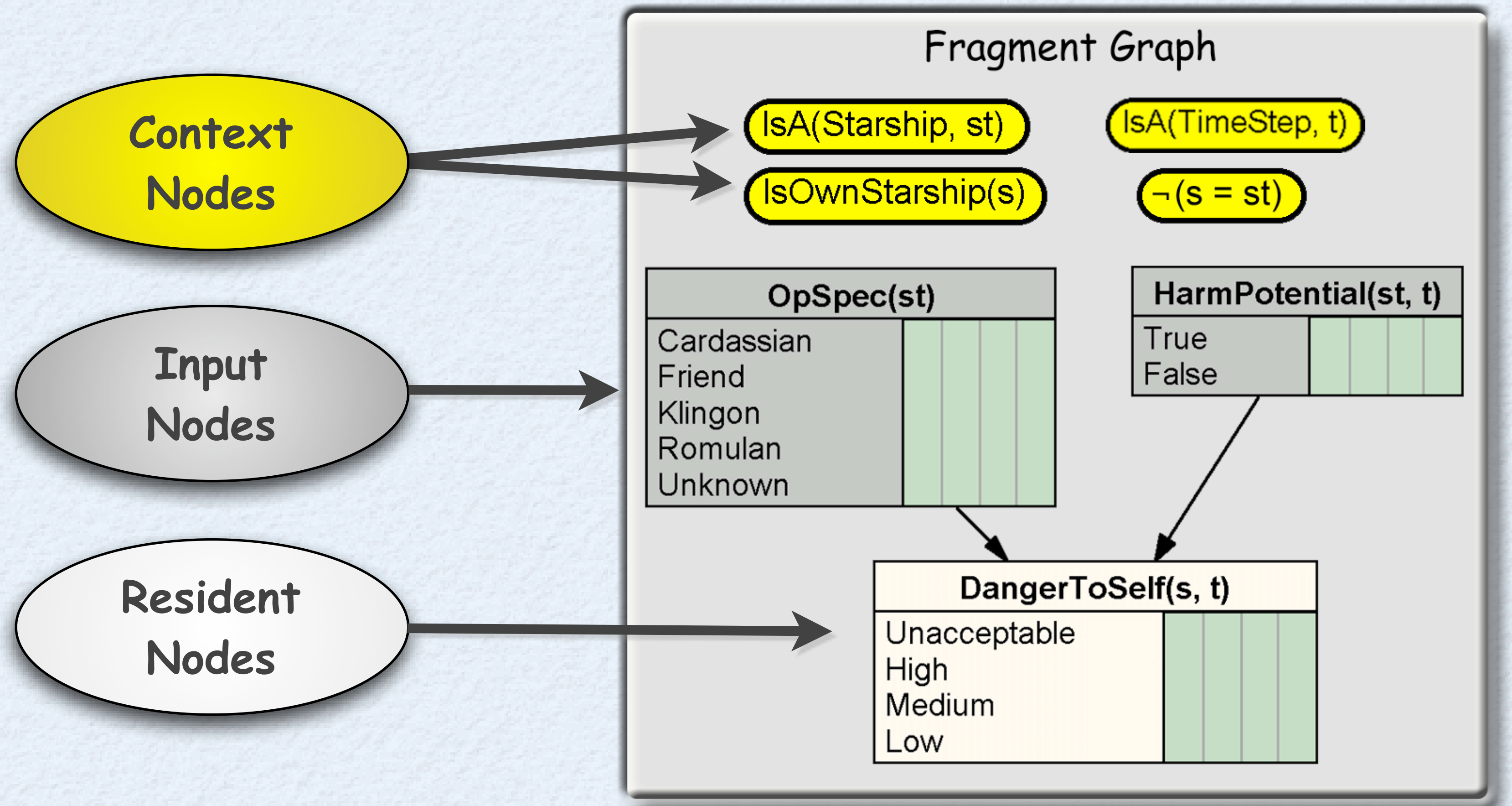

The danger to self MFrag

Implementation Approach

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- ★ Upper Ontology (e.g. OWL-S)

  vs.

  Semantic Extension (e.g. SWRL)

Implementation Approach

- Upper Ontology (e.g. OWL-S)

  vs.

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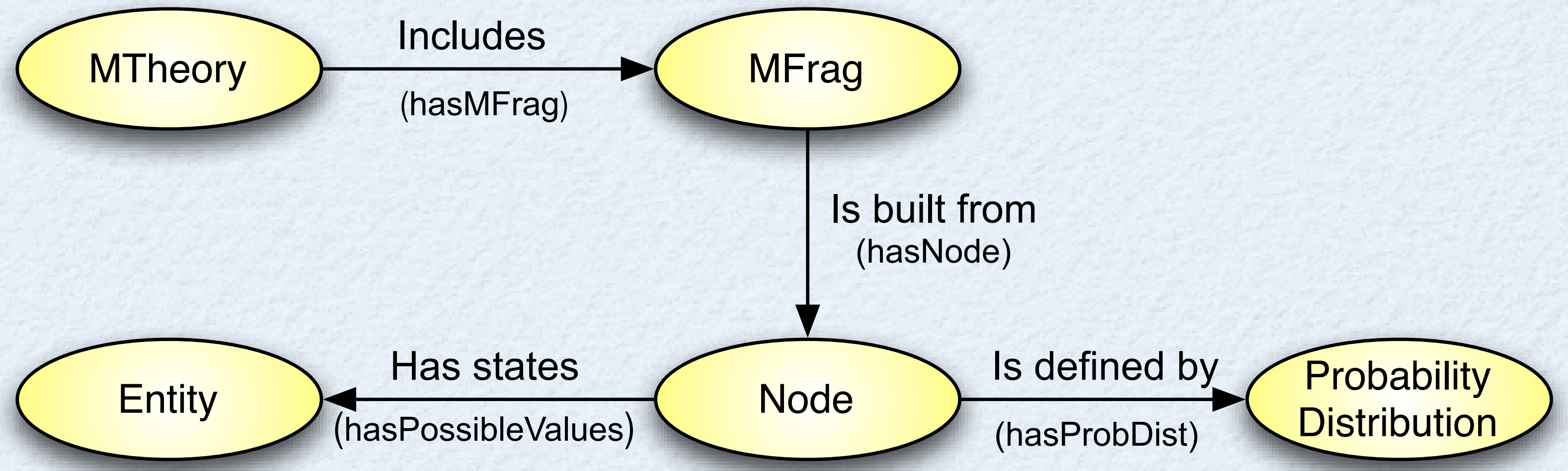
- Initial Approach: An upper ontology for probabilistic systems



MEBN/PR-OWL

MEBN MFrag	**PR-OWL Representation**
IsA(TimeStep, tprev)	<none>
IsA(Zone, z)	
IsA(Starship, st)	
IsA(TimeStep, t)	
tprev = 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, tprev)	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

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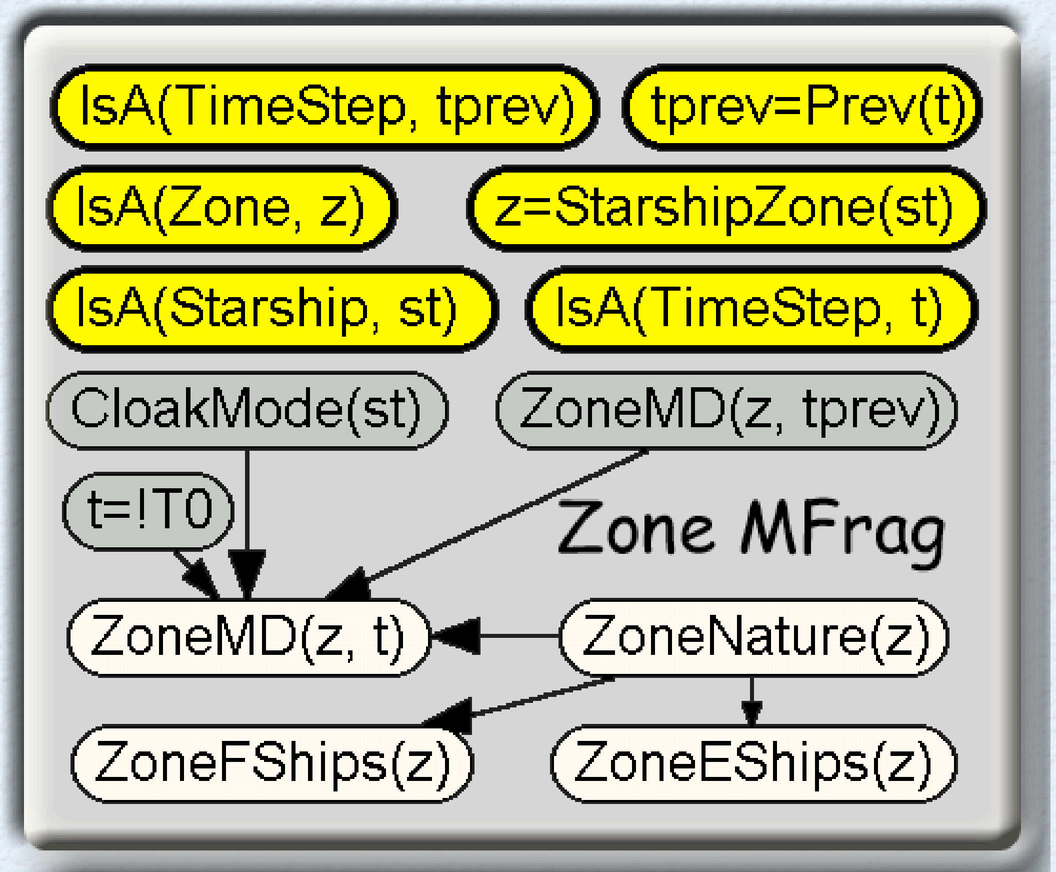
t = !T0	Z_TequalT0_inpu
ZoneMD(z, t)	Z_ZoneMD
ZoneNature(z)	Z_ZoneNature
ZoneFShips(z)	Z_ZoneFShips
ZoneEShips(z)	Z_ZoneEShips



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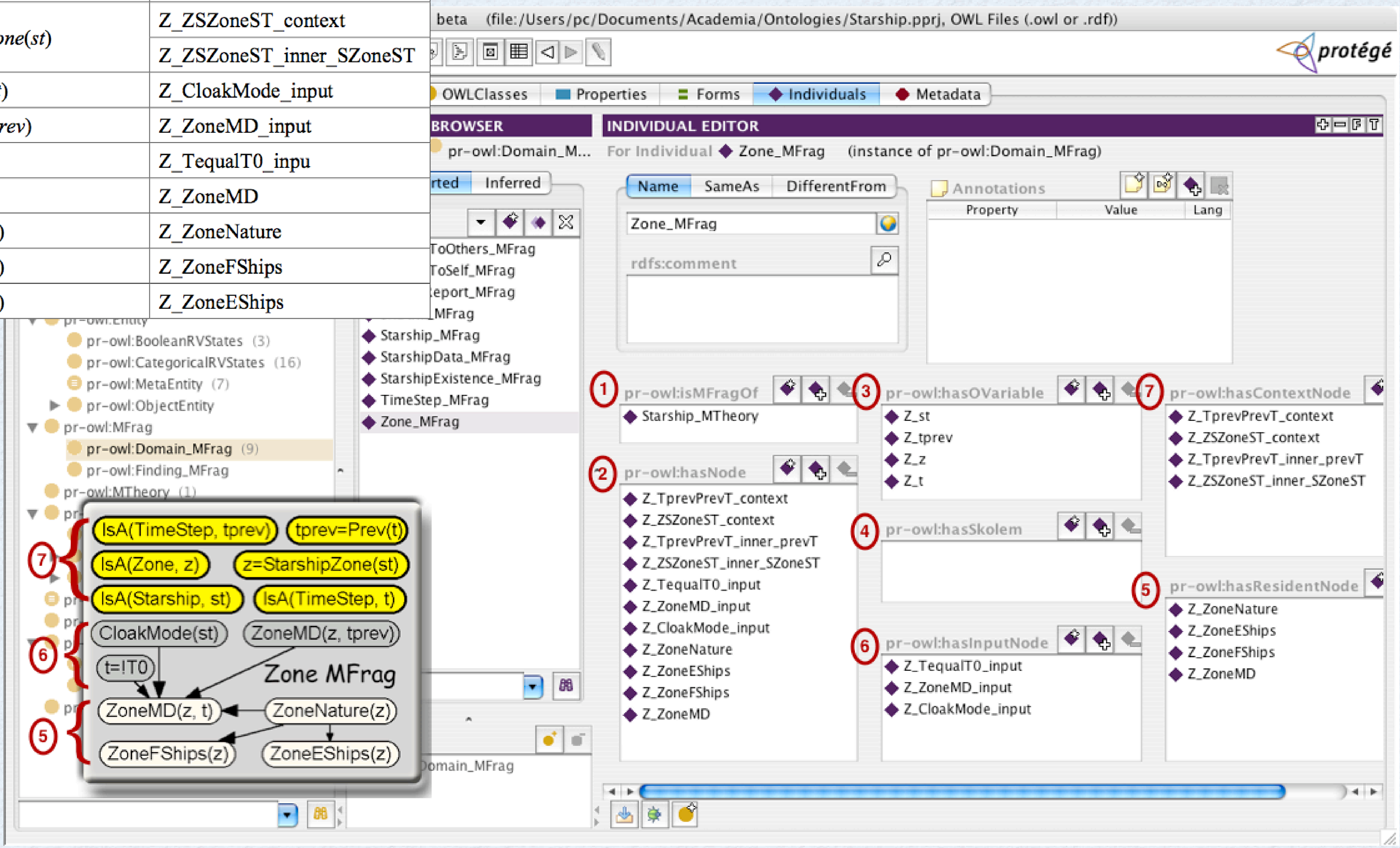


The Road Ahead

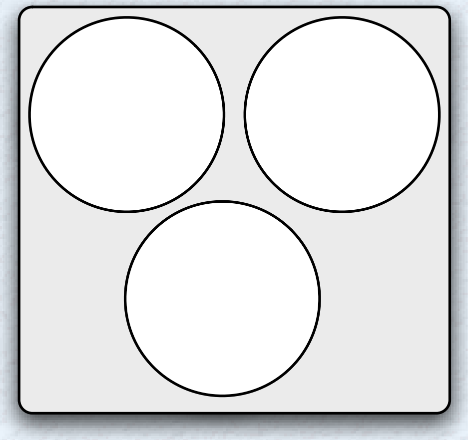
The Road Ahead

- 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

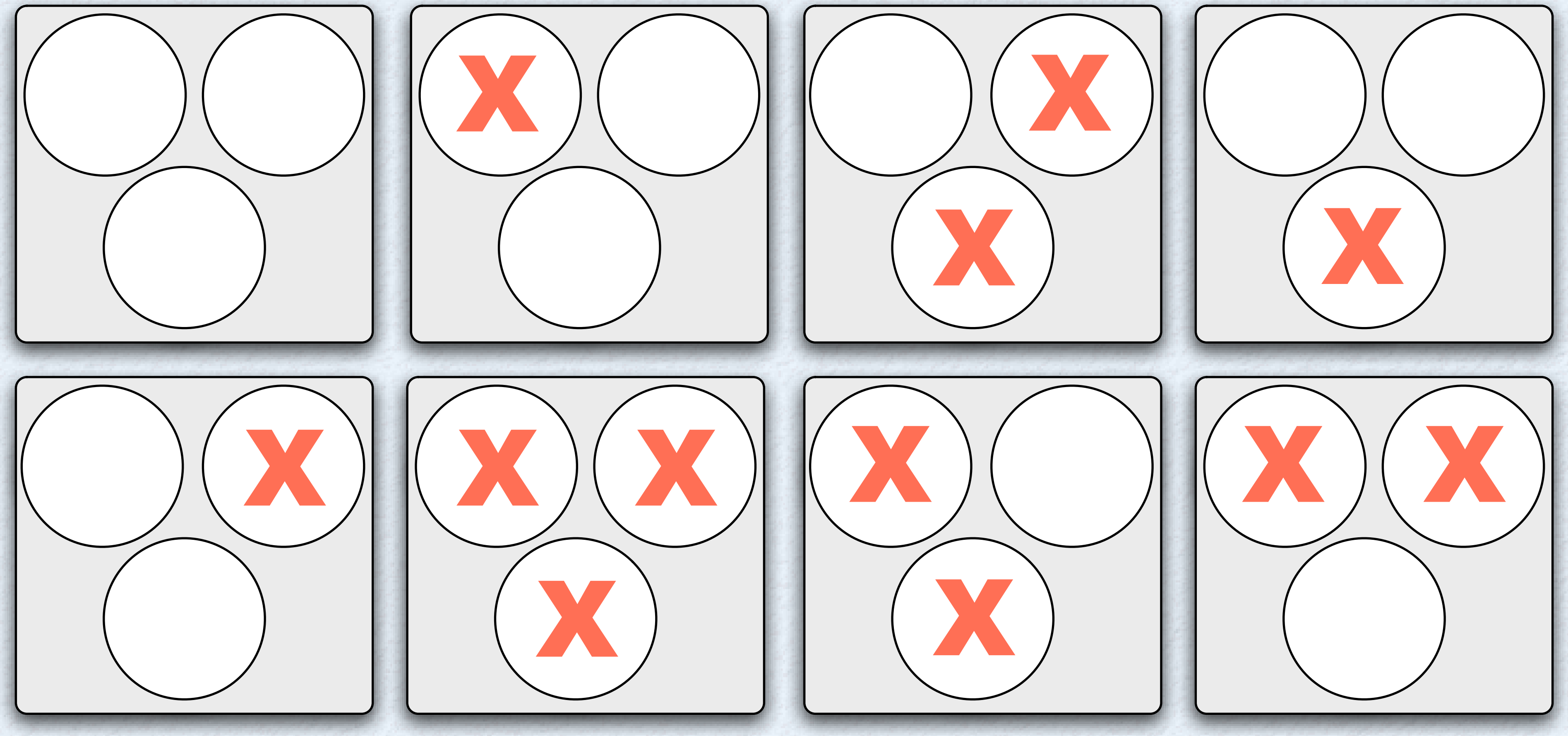
Three binary variables



Logical vs. Plausible

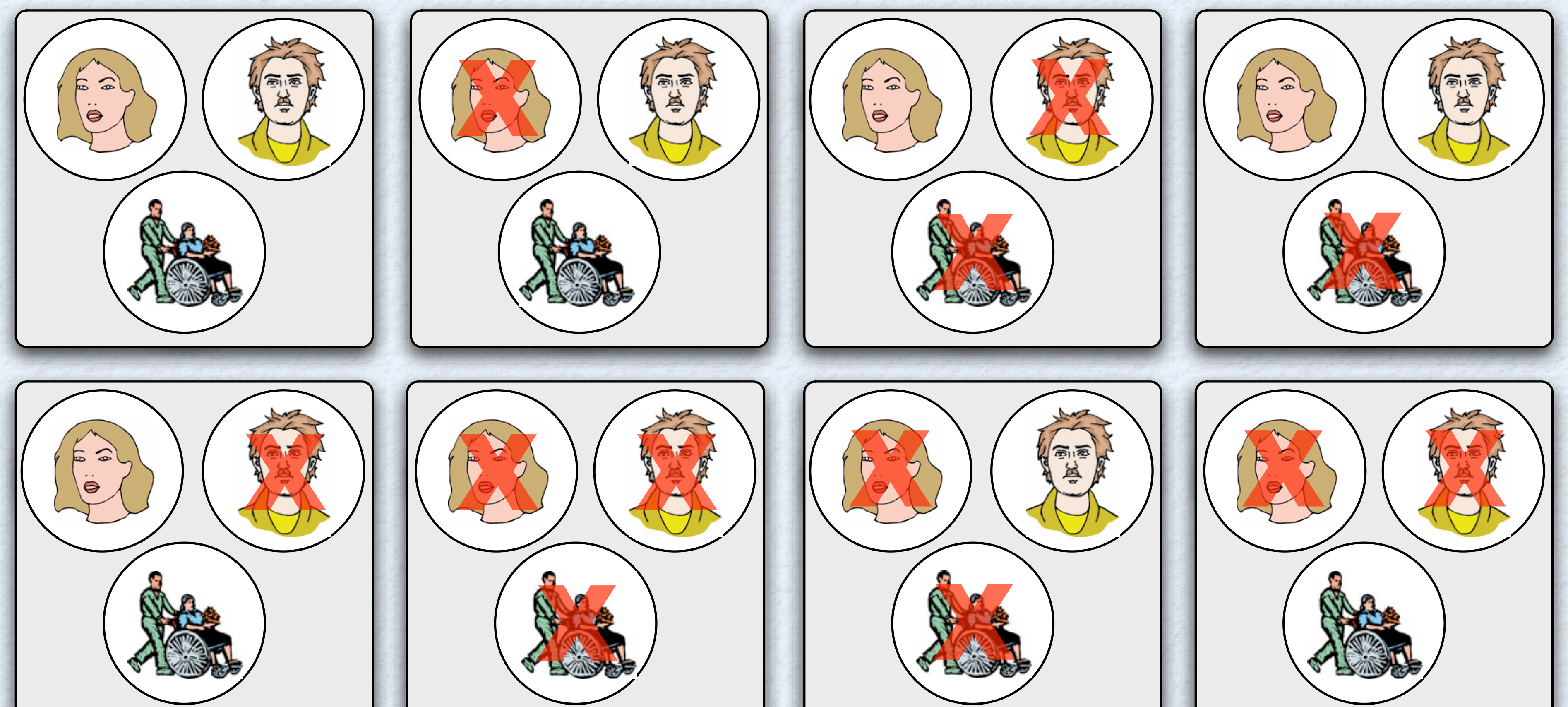
Three binary variables

$2^3 = 8$ possible combinations



Logical vs. Plausible

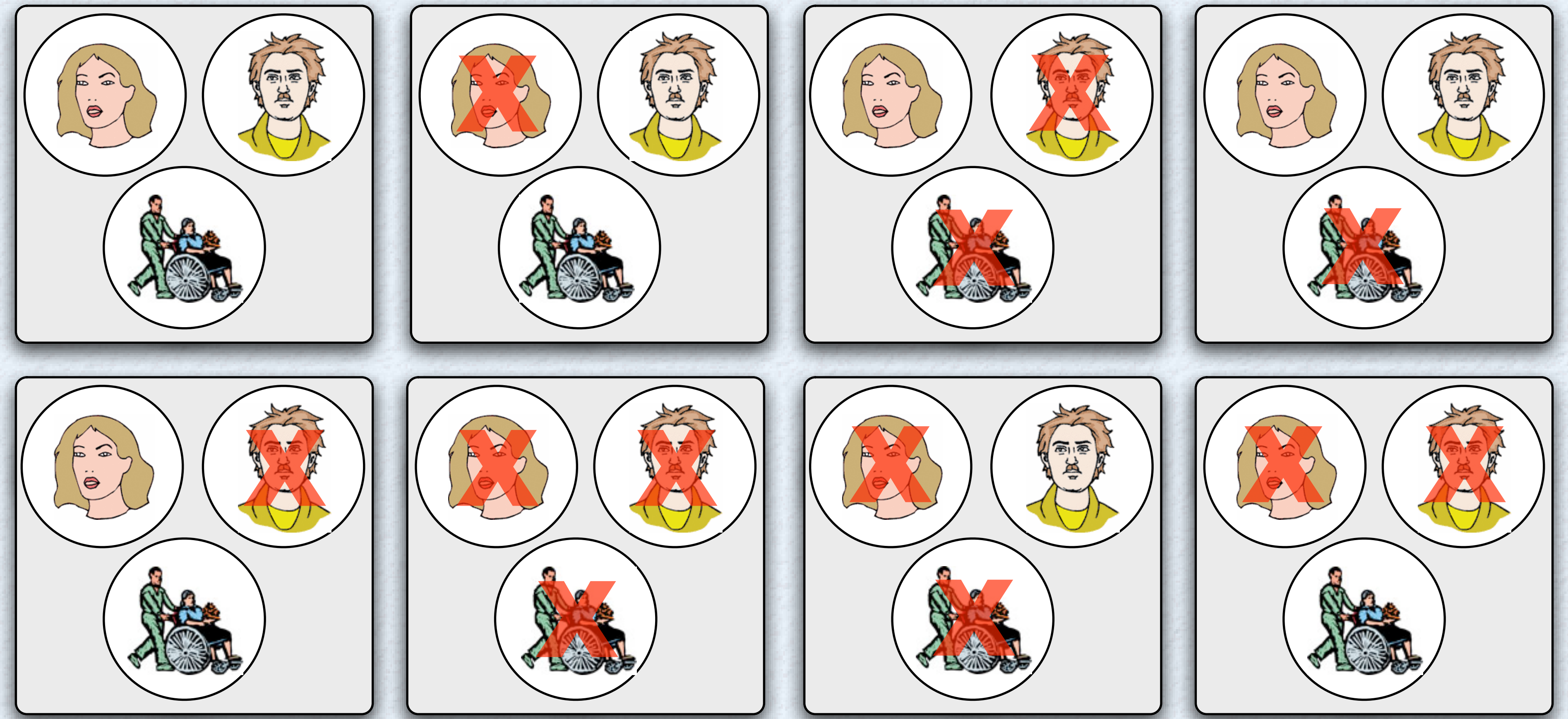
Does mom have transportation to the doctor tomorrow?



Logical vs. Plausible

Does mom have transportation to the doctor tomorrow?

1) Yes, if Lucy or Pete gives her a ride.
Otherwise, no.

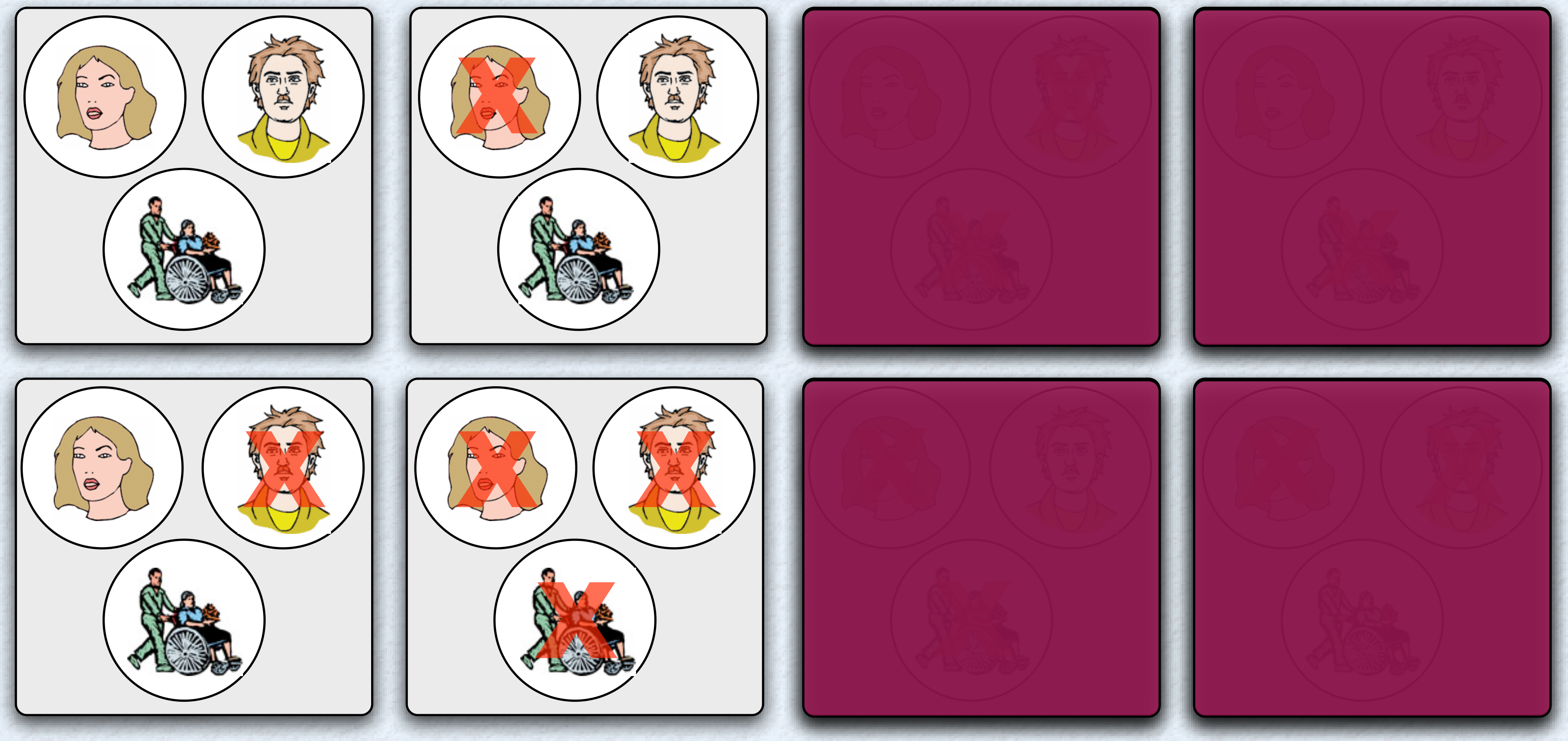


Logical vs. Plausible

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%



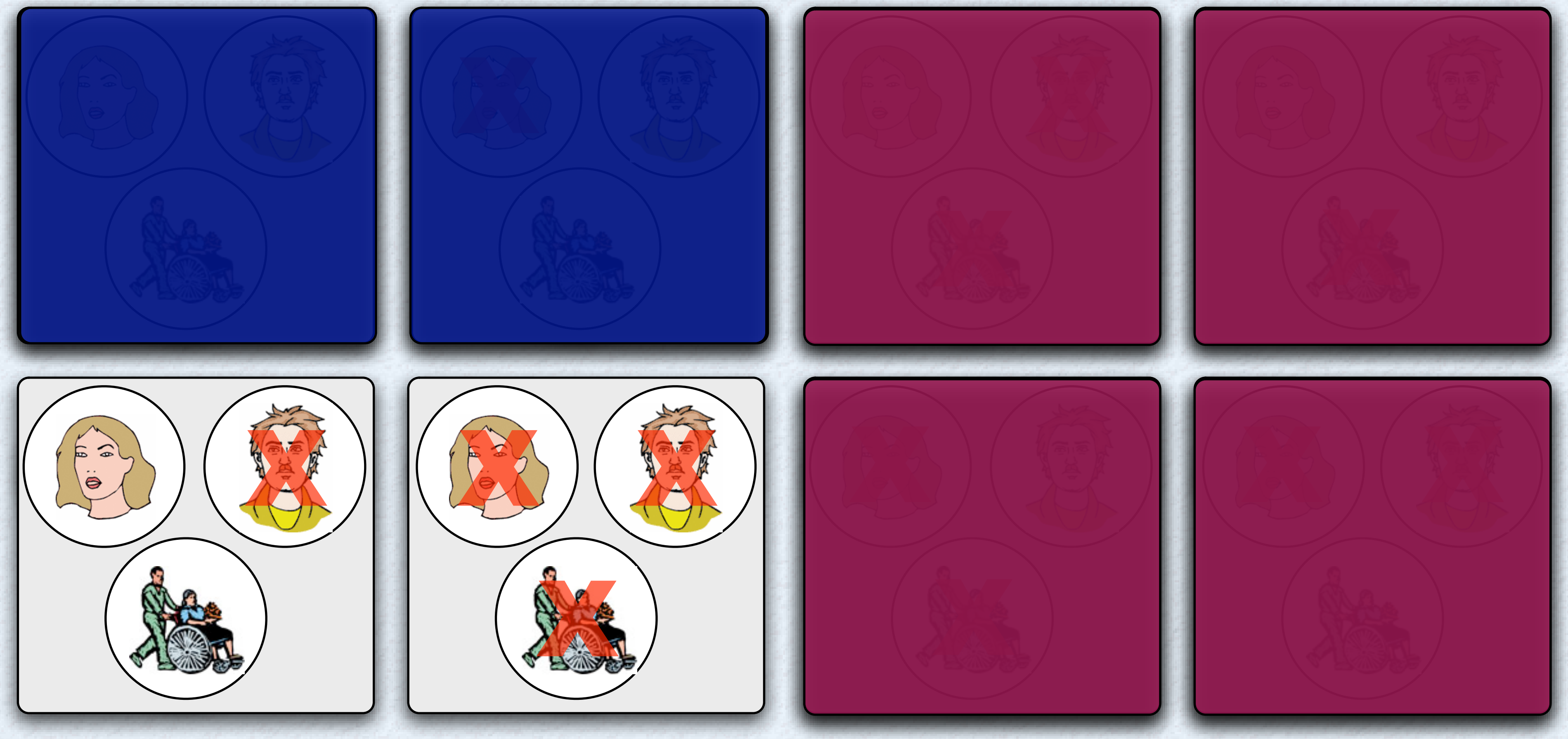
Logical vs. Plausible

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.

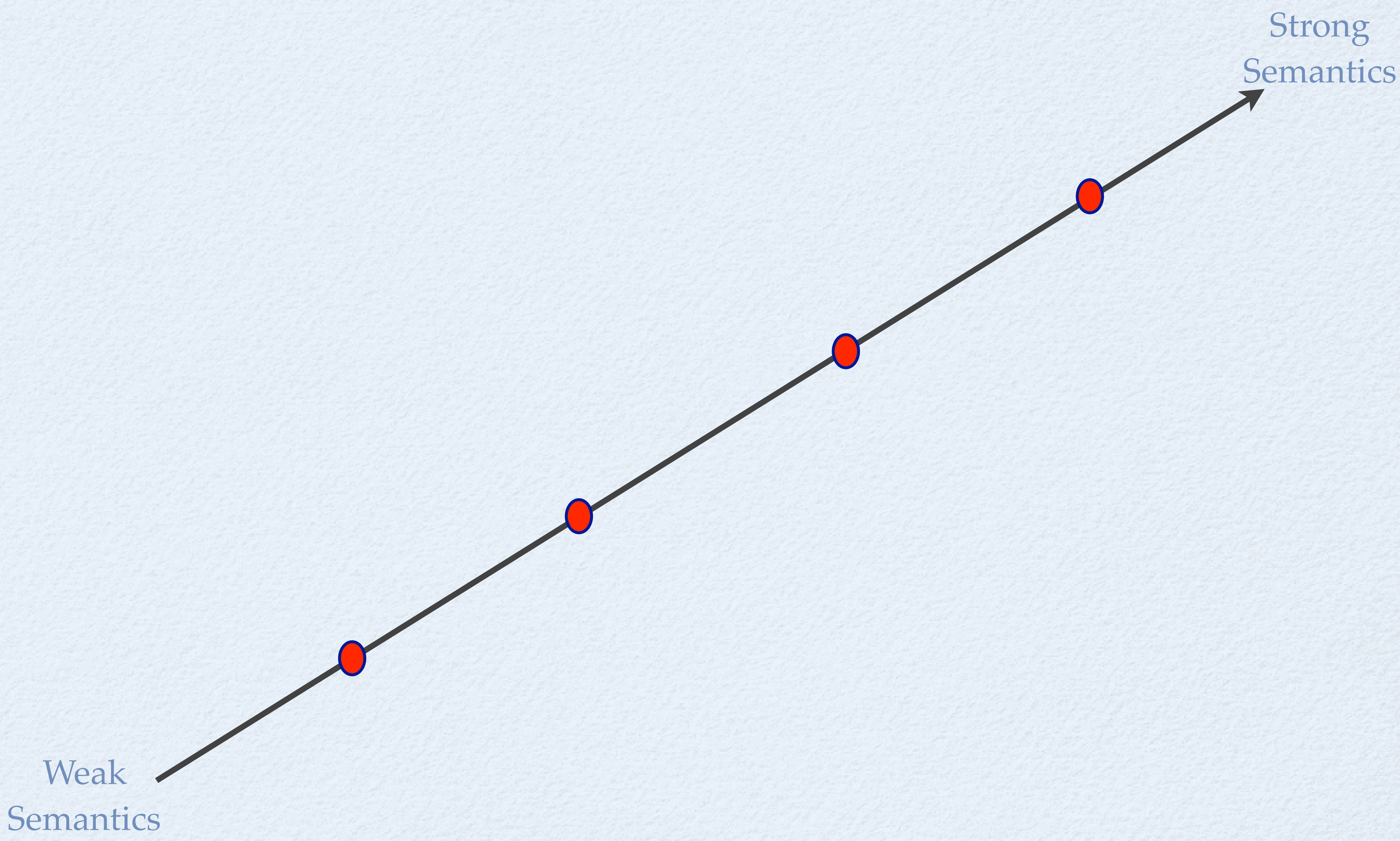
	Logical	Plausible
Yes	**?**	**50%**
No	**?**	**50%**



The Ontology Spectrum

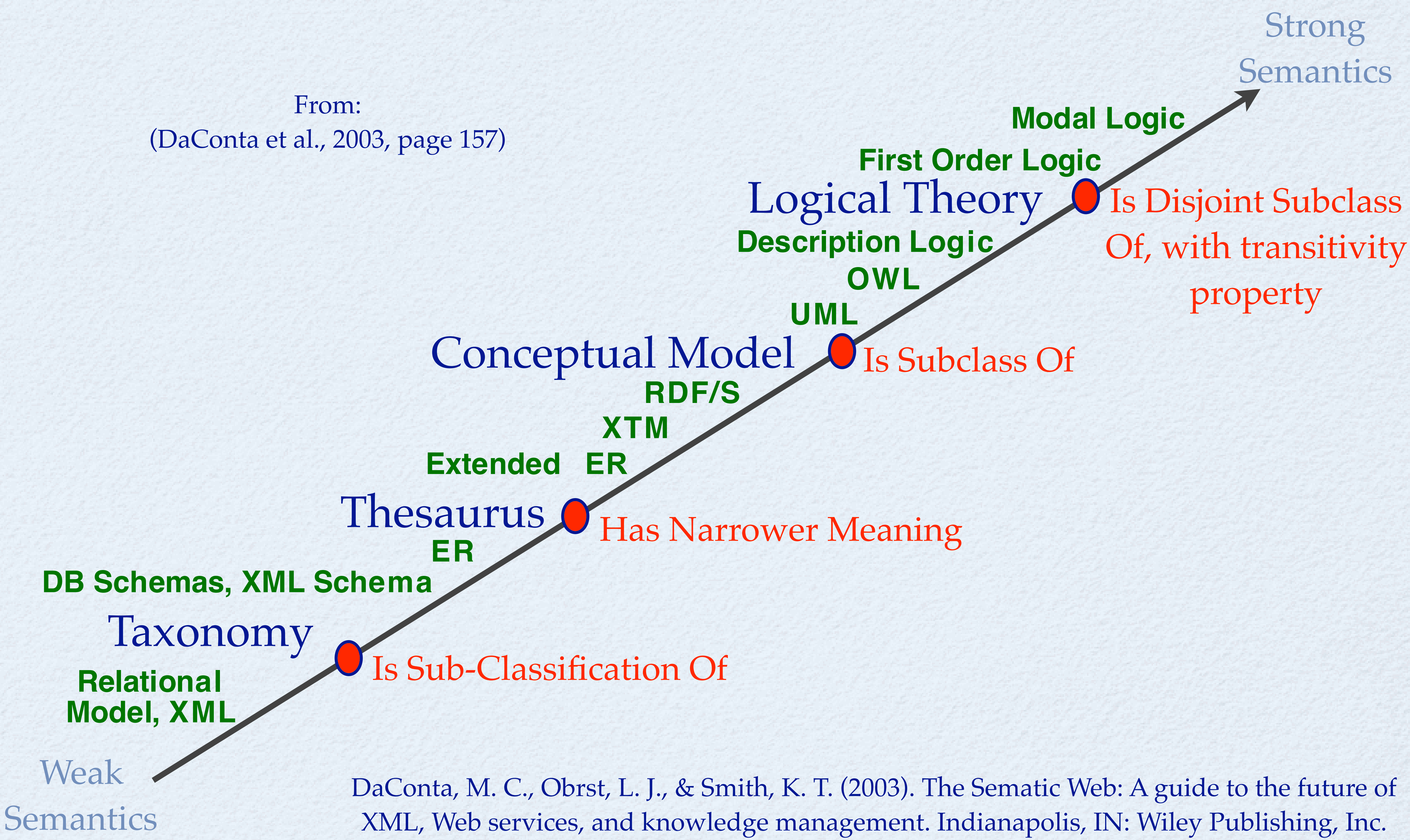
Weak
Semantics

The Ontology Spectrum



The Ontology Spectrum

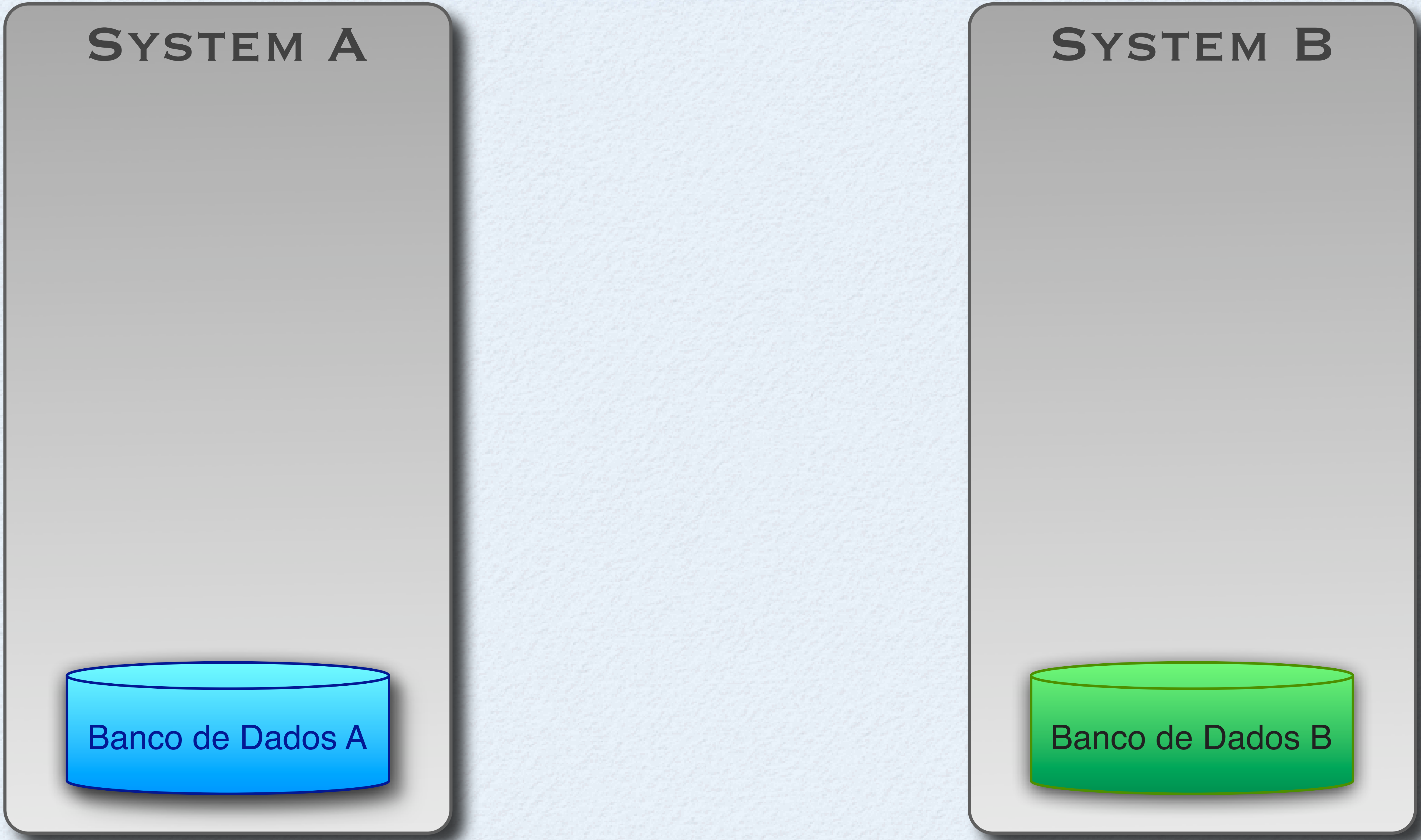
From:
(DaConta et al., 2003, page 157)



DaConta, M. C., Obrst, L. J., & Smith, K. T. (2003). The Sematic Web: A guide to the future of XML, Web services, and knowledge management. Indianapolis, IN: Wiley Publishing, Inc.

System Interaction

System Interaction



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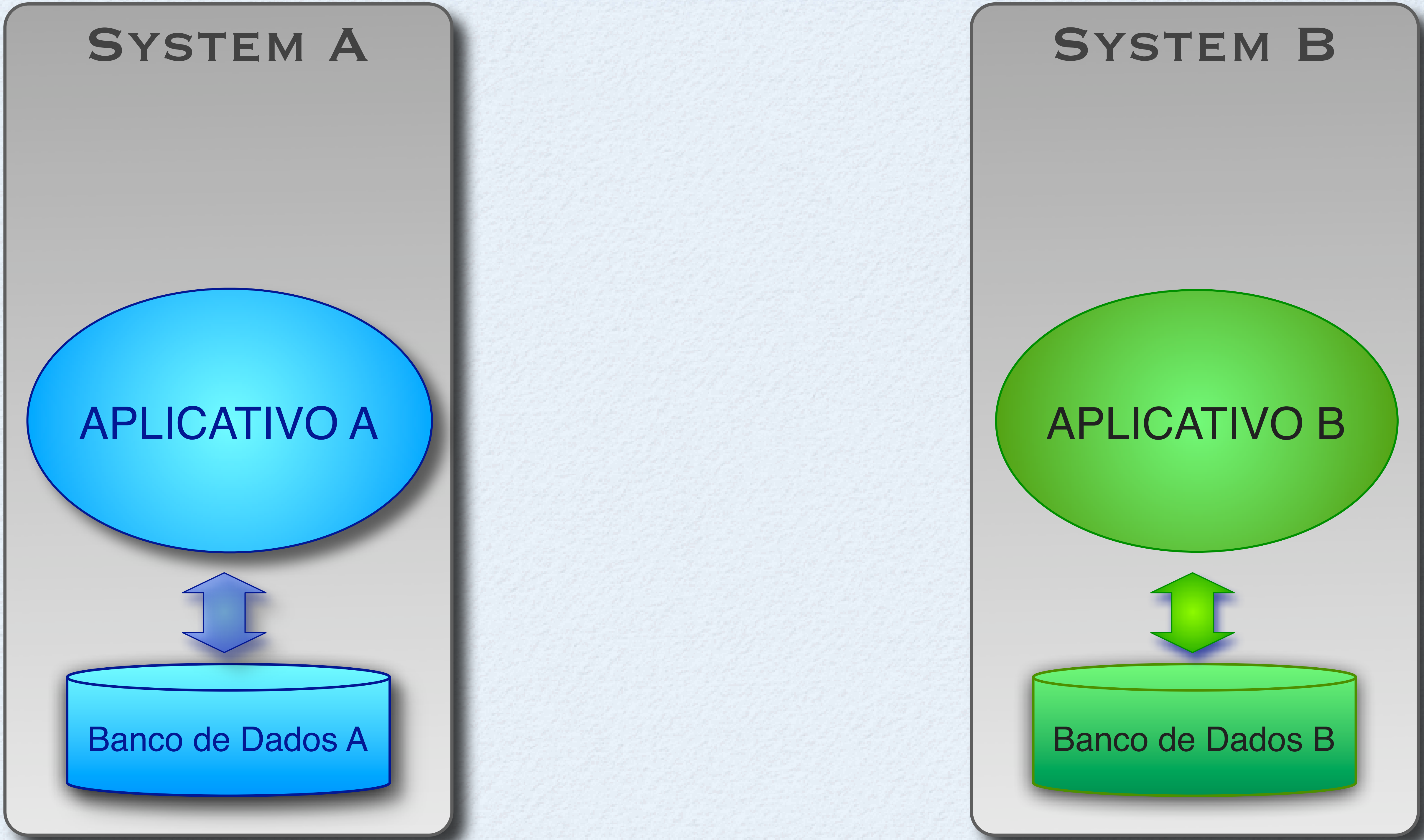

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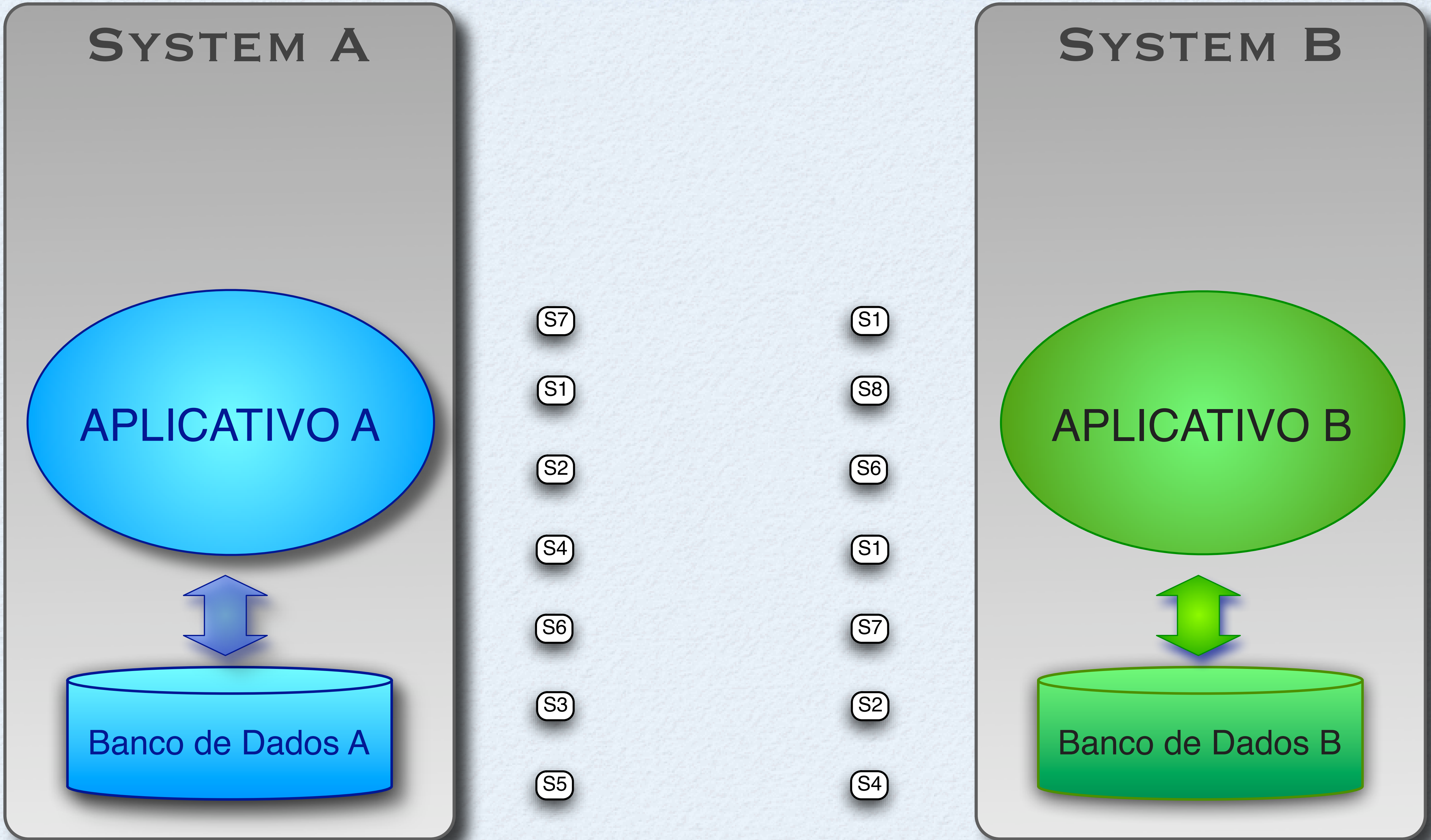
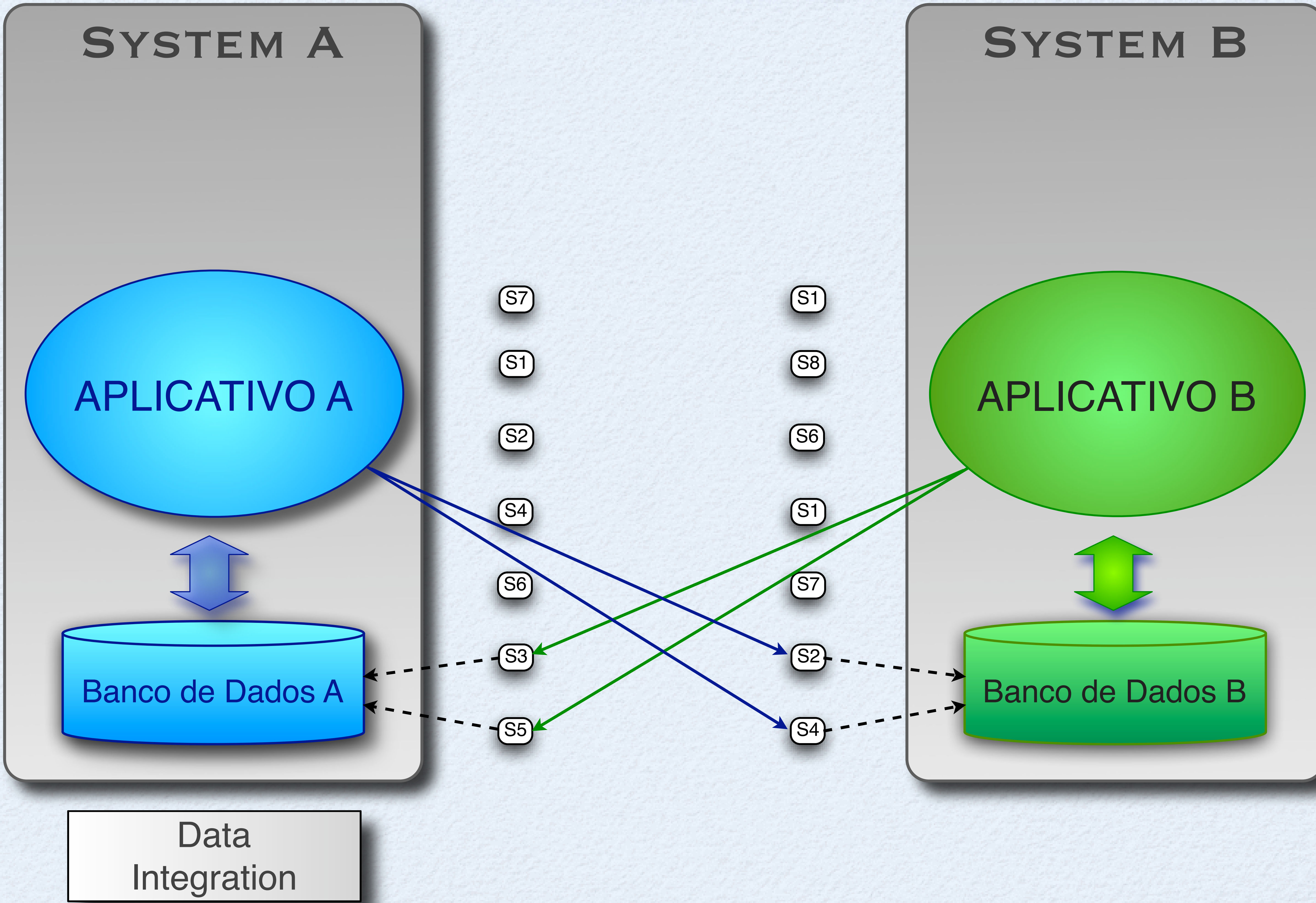


SYSTEM INTERACTION



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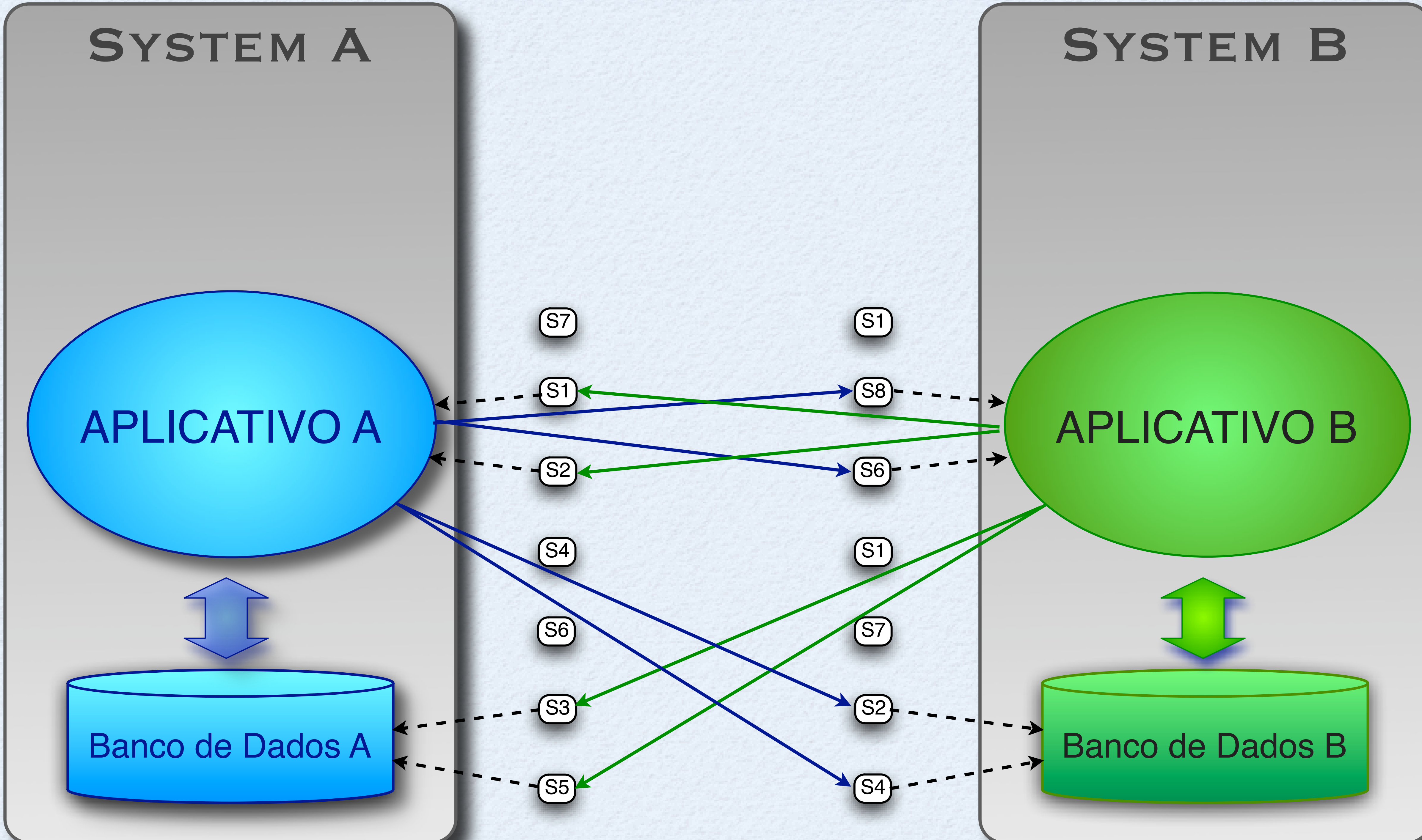
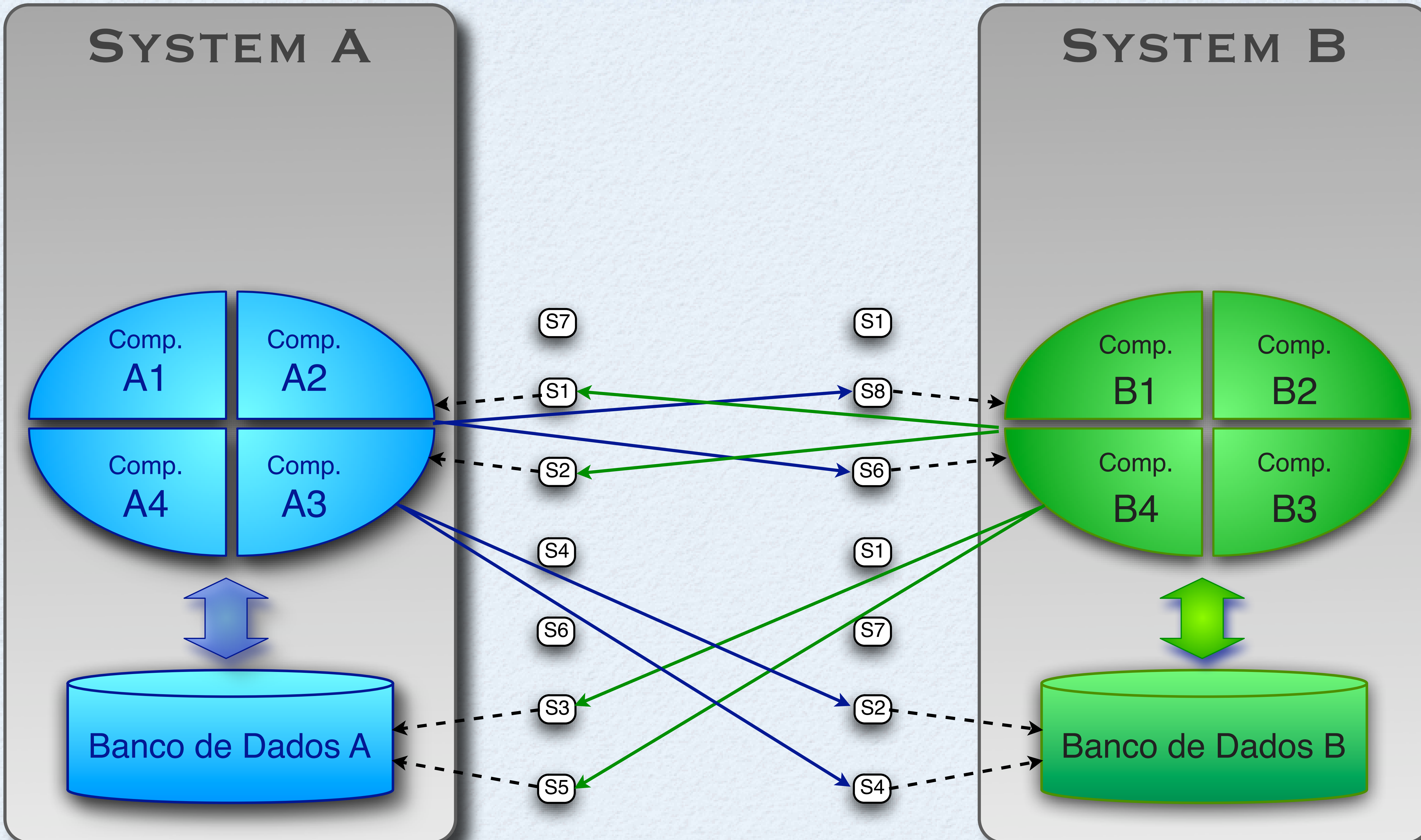


Data Integration	Application Integration

System Interaction



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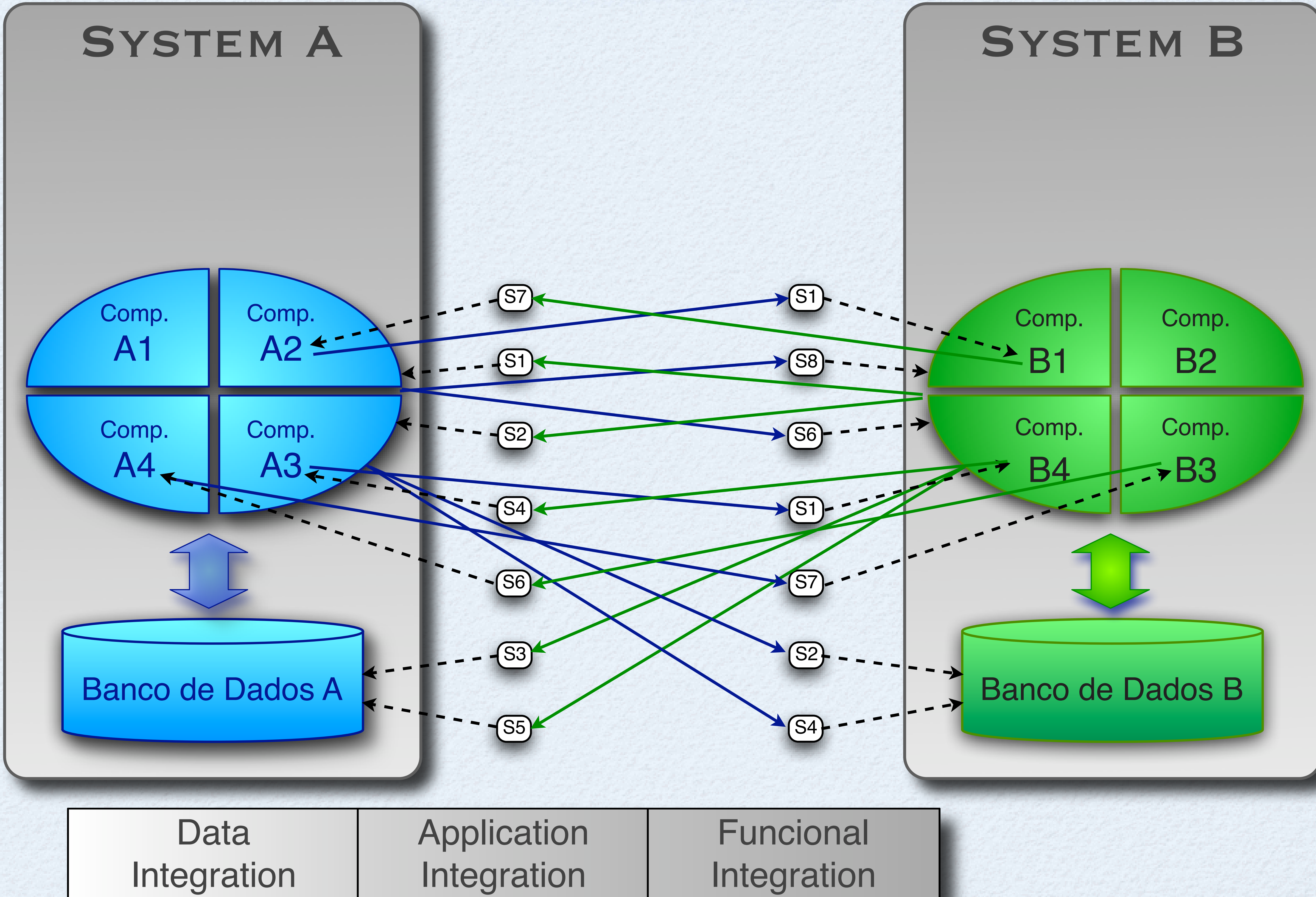
SYSTEM INTERACTION



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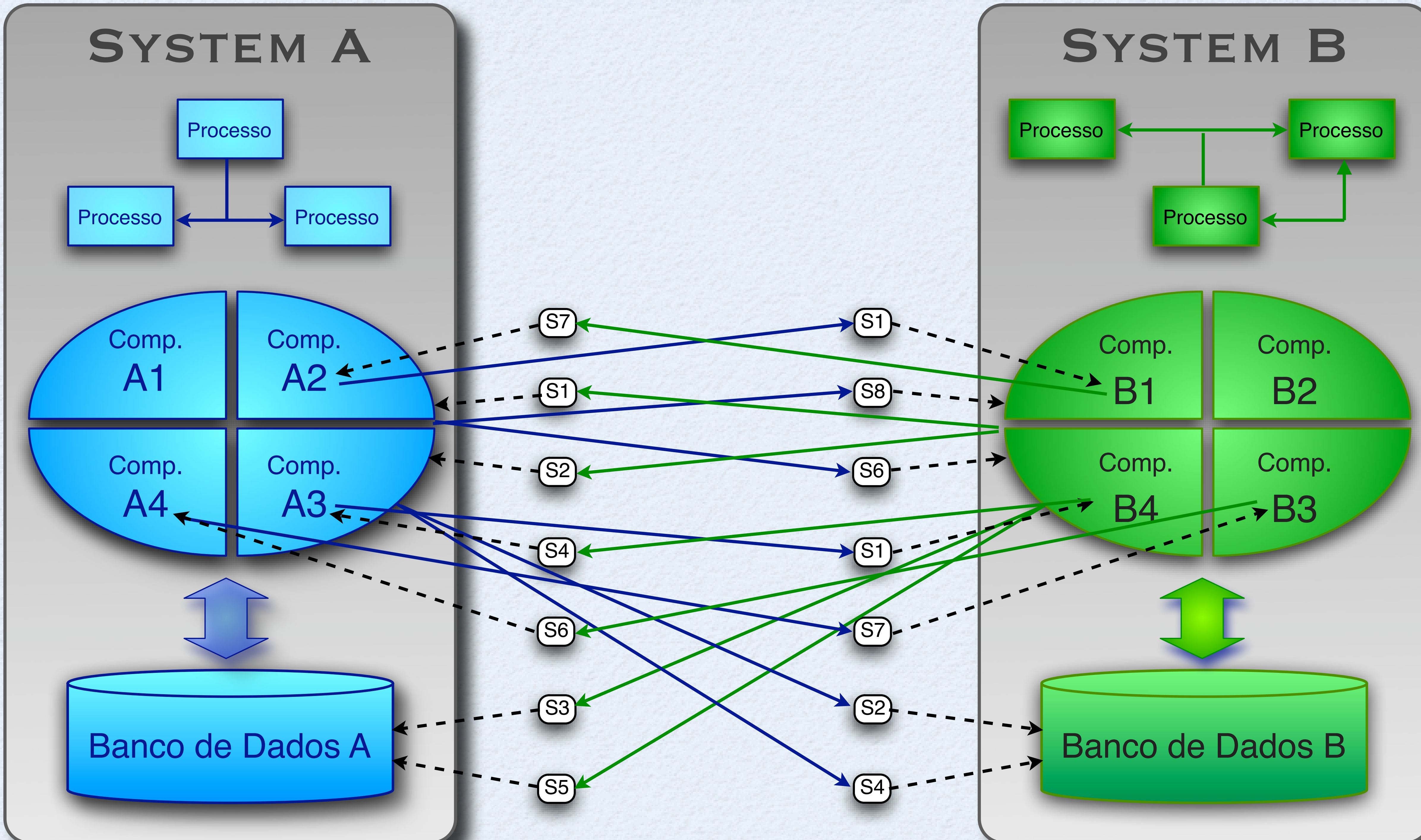

Data Integration	Application Integration	Funcional Integration

SYSTEM INTERACTION