



Emergent Connectors for
Eternal Software Intensive Networked Systems



Interopérabilité dans les systèmes de l'Internet du Futur : Des modèles aux middleware émergents



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Travail collaboratif au sein de CONNECT

Remerciements spéciaux à Amel Bennaceur, Nikolaos Georgantas, Rachid Saadi, Gordon Blair, Paul Grace, Paola Inverardi, Romina Spalazzese



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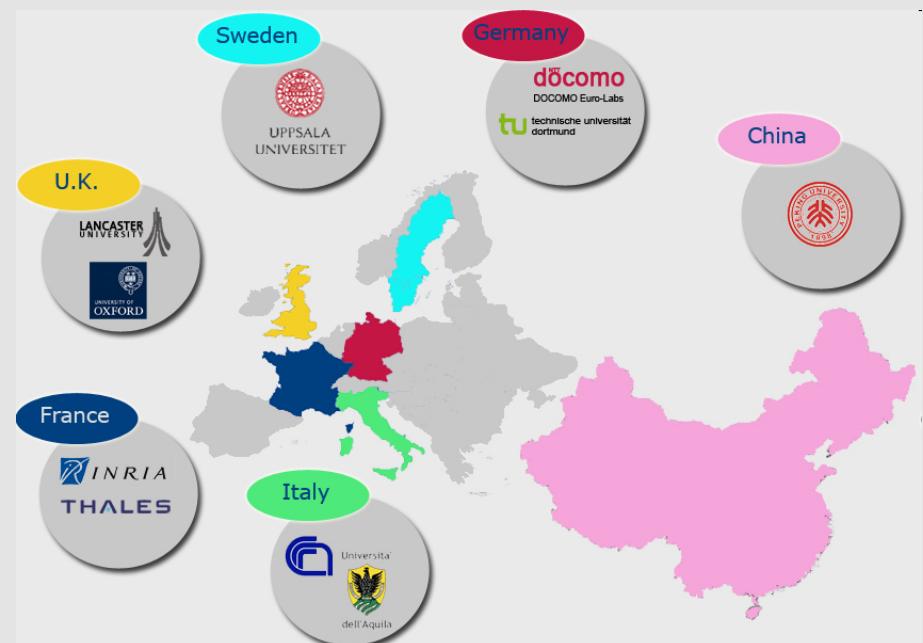
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The FP7 ICT FET CONNECT Project

- Overcoming the interoperability challenge of today's and tomorrow's complex distributed systems

→ A run-time model-centric approach to eternal interoperability

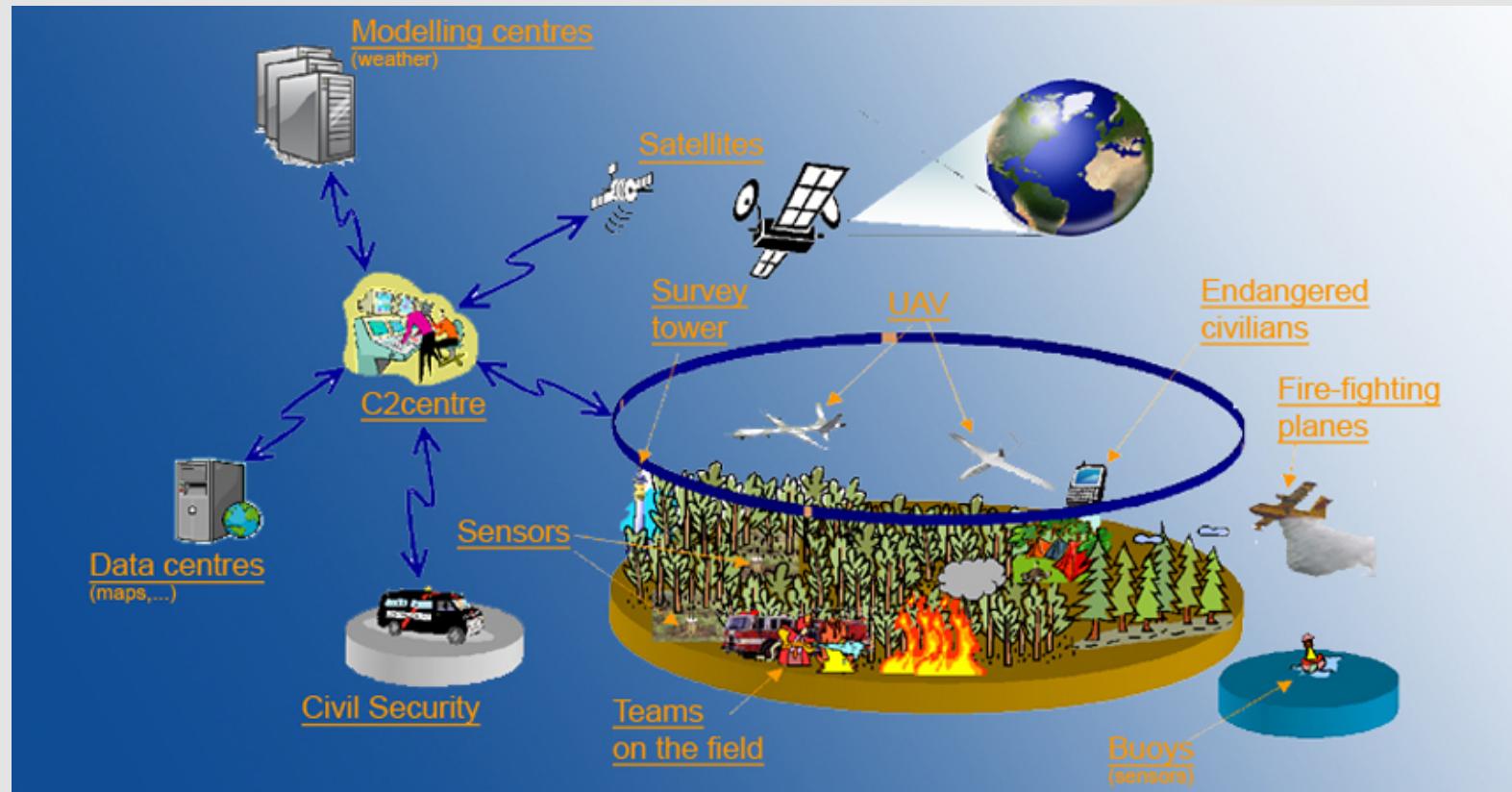


www.connect-forever.eu

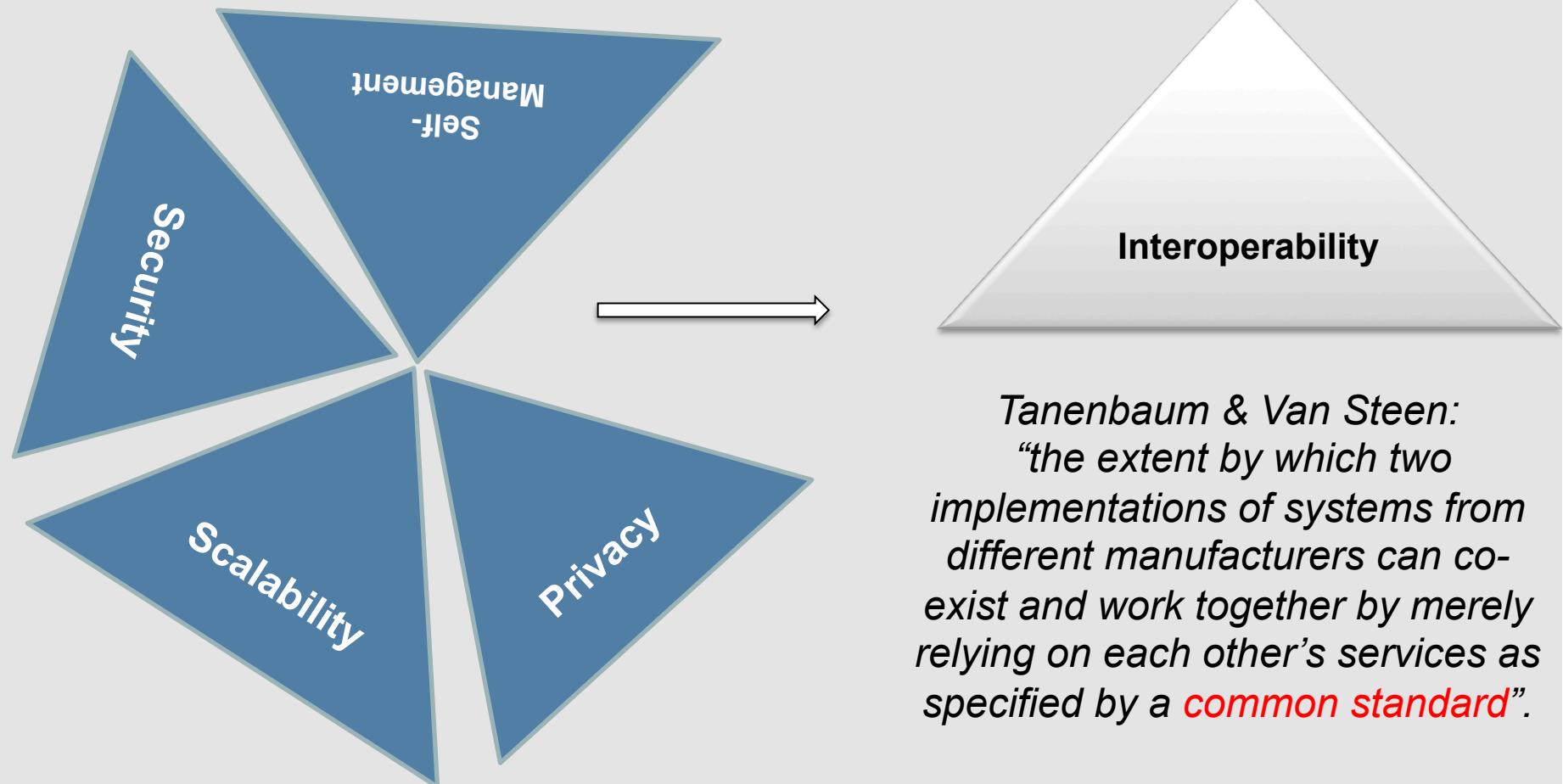
Meeting the Challenge of Interoperability in the Future Internet – Outline

- Interoperability in complex distributed systems
- Emergent middleware synthesis
- The CONNECT architecture enabling emergent middleware
- Conclusions

Illustrating the challenges Global Monitoring for Environment & Security



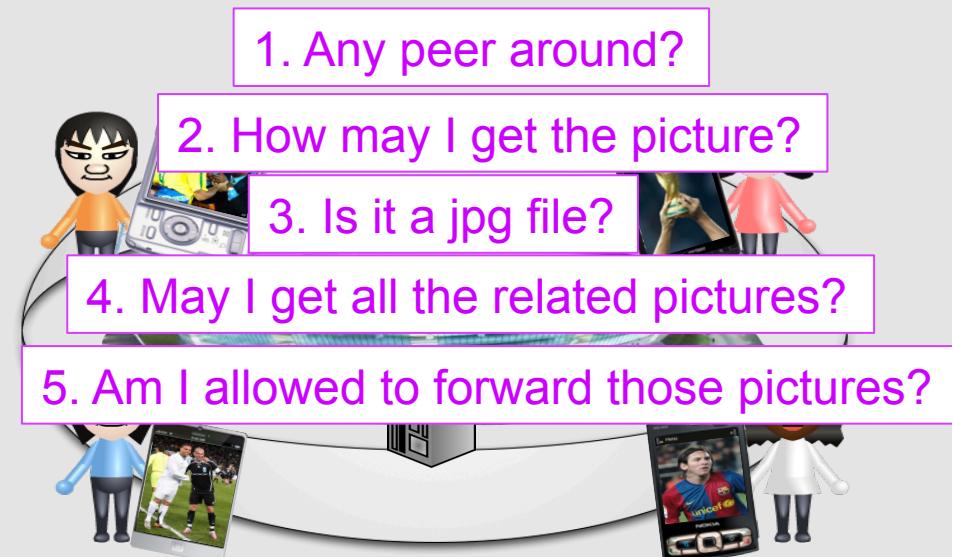
Interoperability Focus



Interoperability Challenges

The Simple Yet Challenging Photo Sharing Scenario

1. Discovery protocol interoperability
2. Interaction protocol interoperability
3. Data interoperability
4. Application interoperability
5. Interoperability of non-functional properties



Approaches to Interoperability



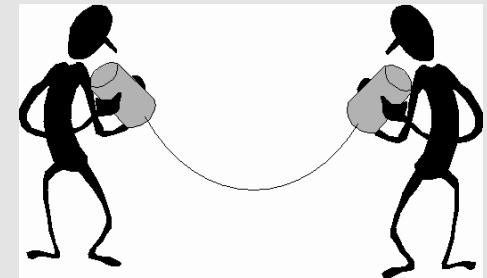
1. A chosen shared language: Standard



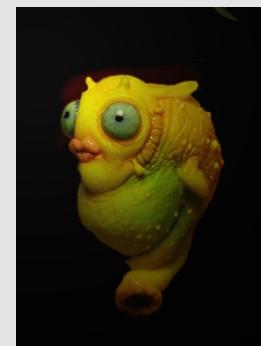
2. One 3rd party translator, e.g., English to French translator: Bridge



4. One speaker talks the other's language: Plugin



3. Auxiliary Languages (e.g. Esperanto): ESB



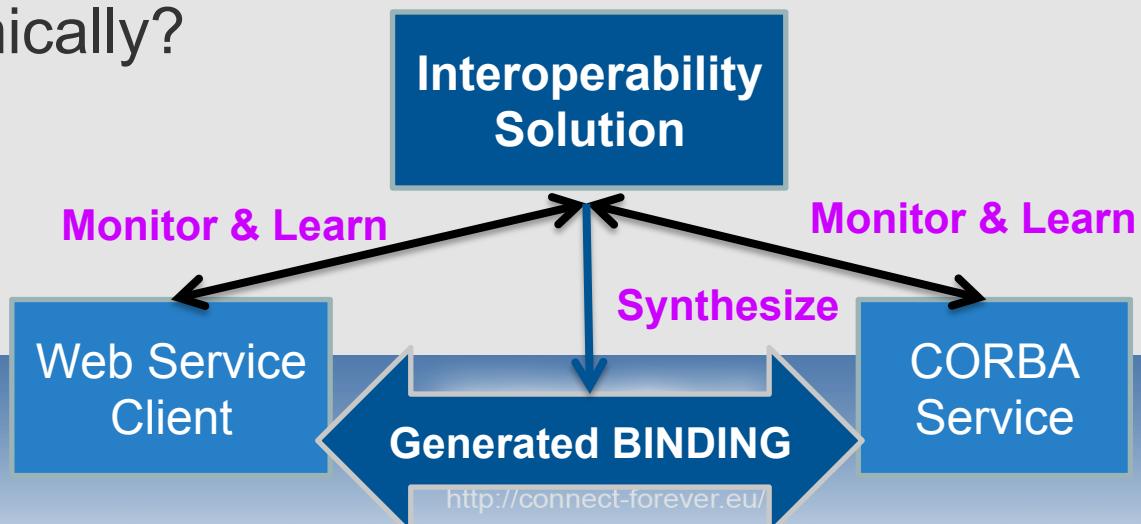
5. Babel fish



We Want Future-Proof Interoperability

5. Babel fish

- Existing approaches to interoperability do not work for distributed systems of tomorrow
 - Fundamental re-think required
 - Towards emergent middleware
 - Can we observe, learn, synthesize and deploy a binding dynamically?



Time to Re-think Middleware

Universal instant messaging



Photo sharing in a stadium

Time to Re-think Middleware

Universal instant messaging

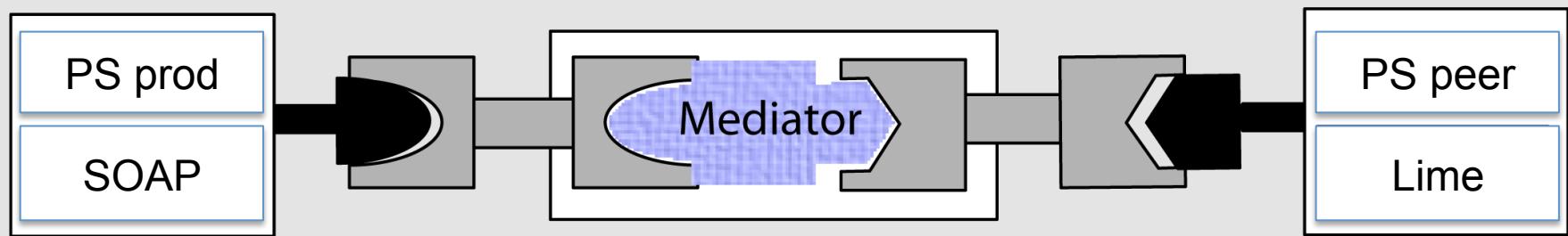
- **Today's middleware fails to achieve interoperability**
 - Pervasive networked systems offering matching functionalities,
 - but implementing highly heterogeneous protocols from application down to middleware layer
- **Need for on-the-fly interoperability**
 - Pervasive networked systems meet on the fly
- **Emergent middleware as a result of protocol composition**
 - Dynamic synthesis of mediation protocols

Photo sharing in a stadium

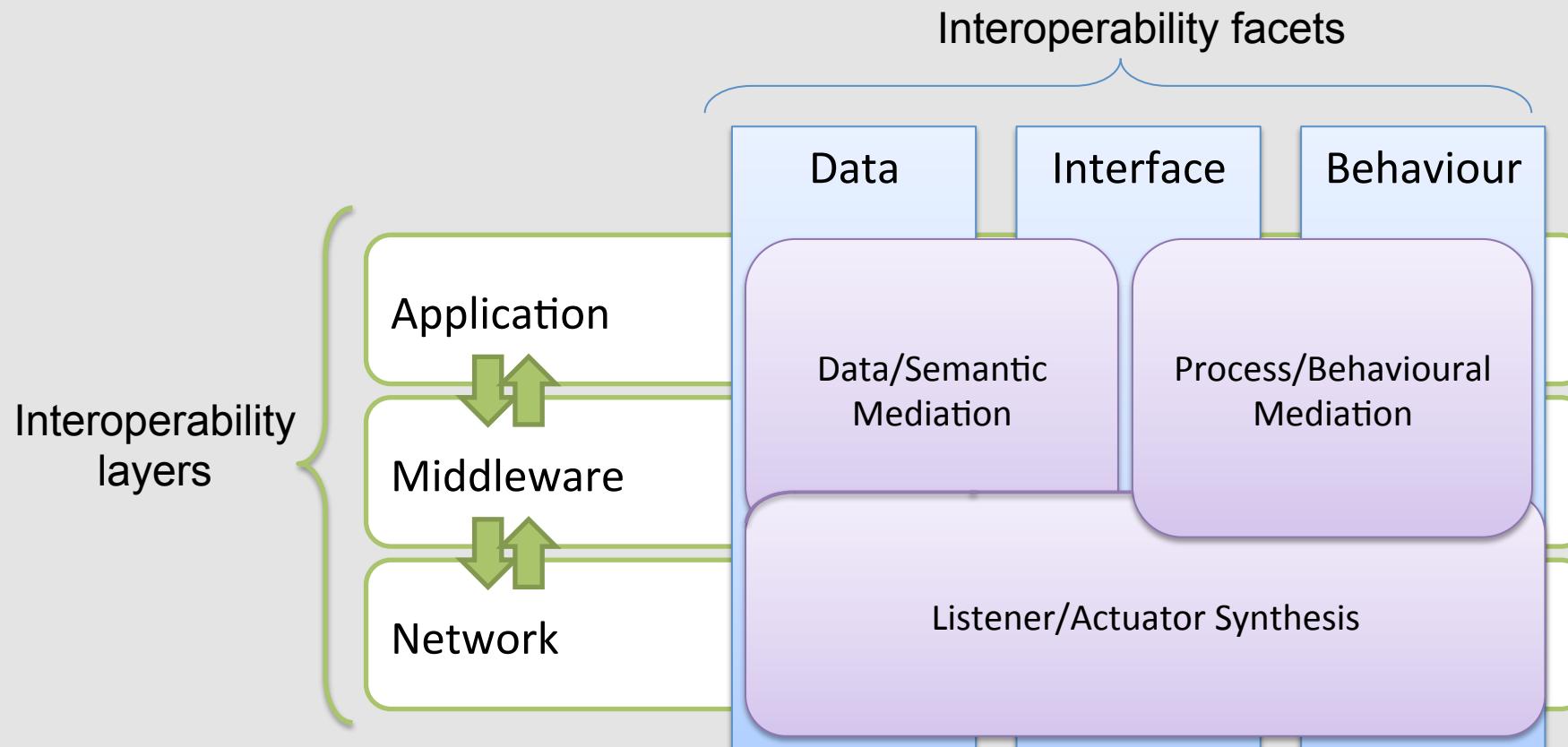
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Mediation Connector aka Emergent Middleware



The Many Facets of Mediation



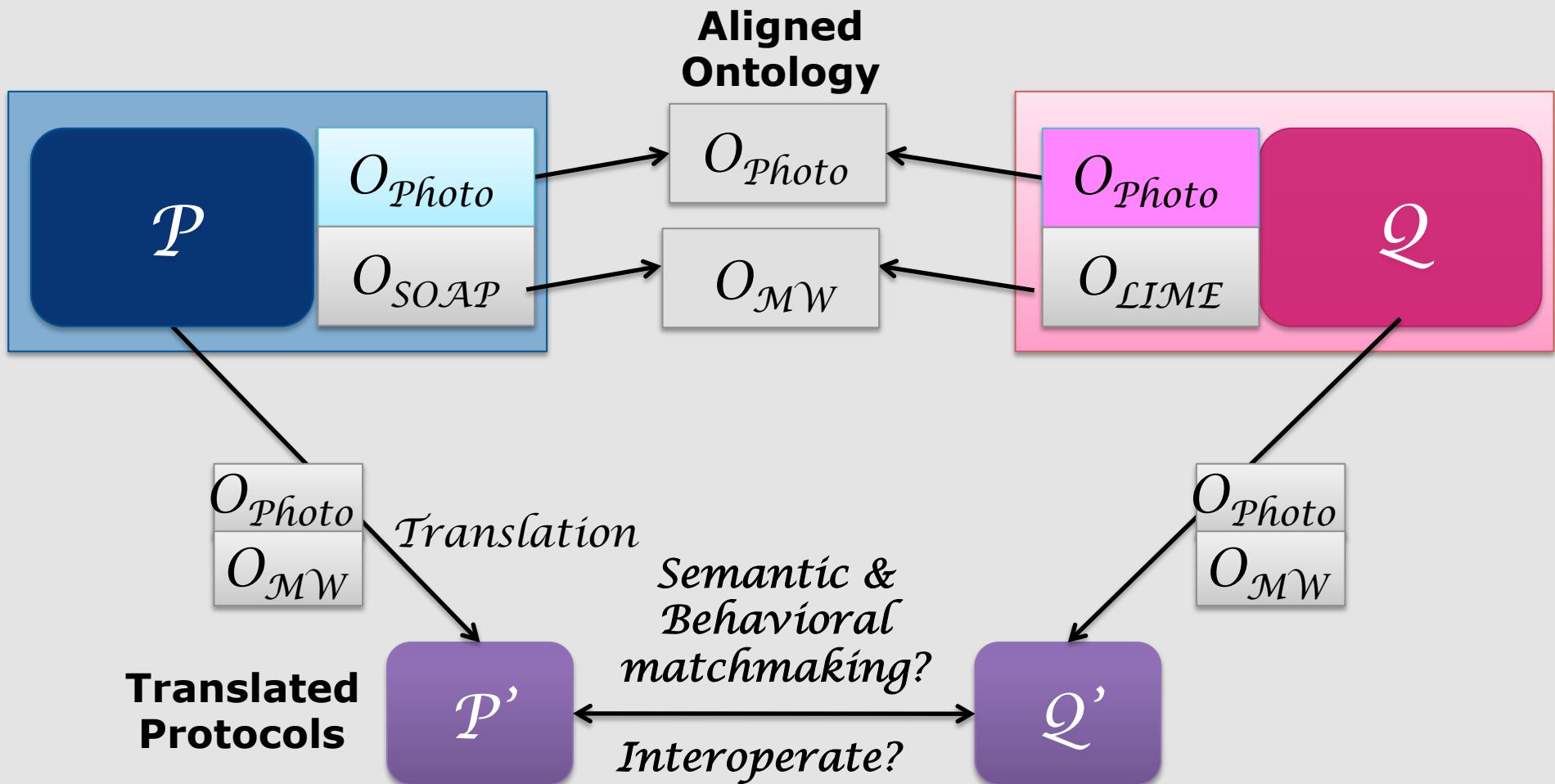
How to make “Mediation Connector” emergent?

The Steps to Emergent Connection

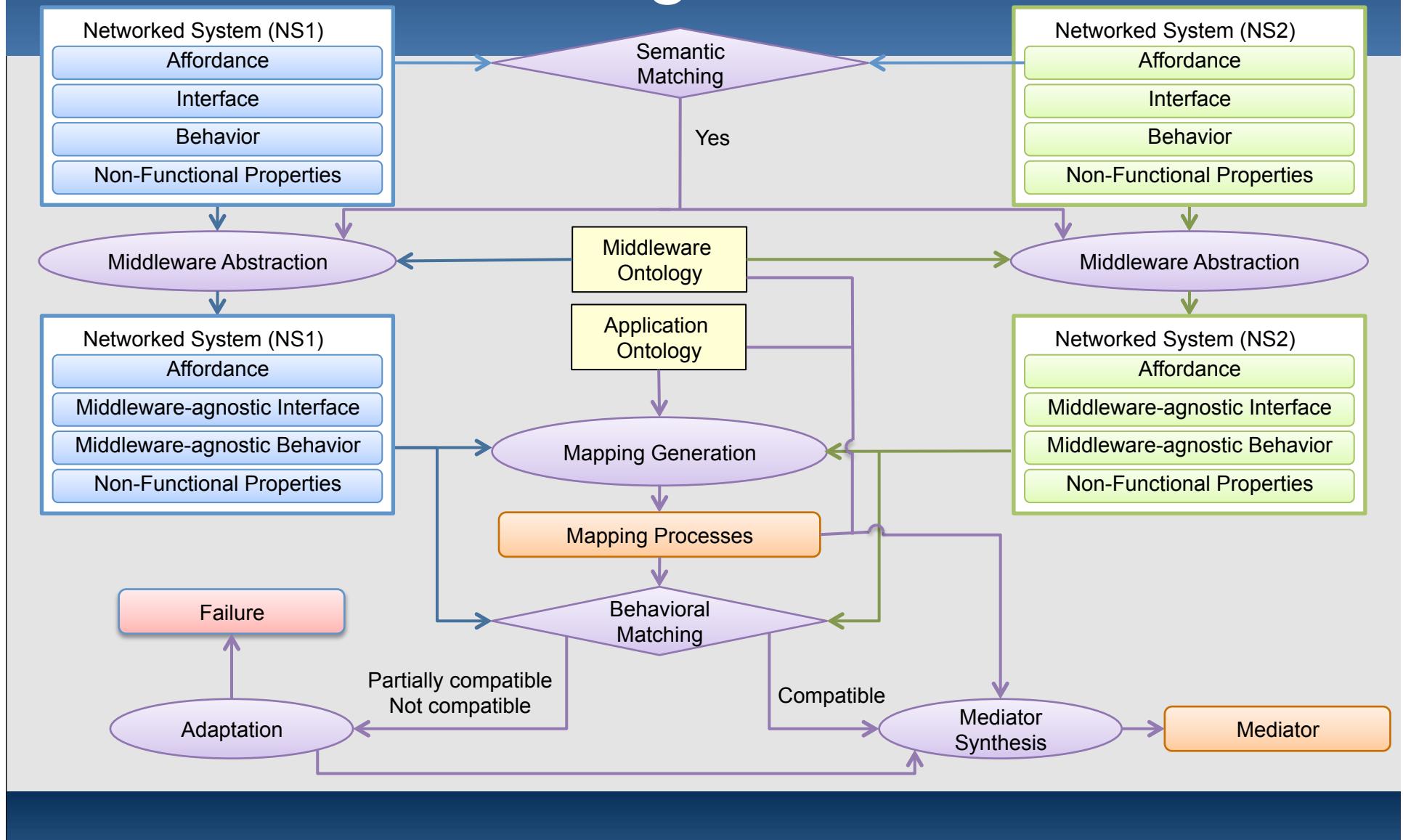
- Find each other aka dynamic service/resource discovery
- Reason about interoperability ability in terms of:
 - Semantics matching
 - Behavioral matching
- Solve behavioural mismatches through mediation

Talking the Same Language

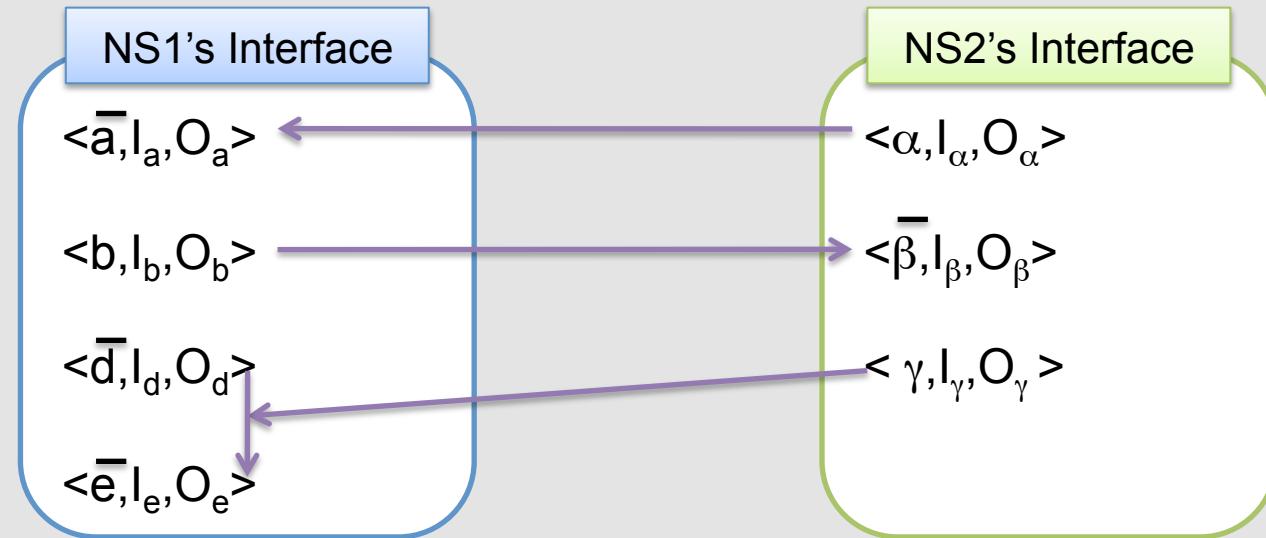
The Key Role of Ontology



Matching: Overview



Matching: 1:n mapping



$$\alpha \sqsubseteq a$$

$$I_a \sqsubseteq I_\alpha$$

$$O_\alpha \sqsubseteq O_a$$

$$b \sqsubseteq \bar{\beta}$$

$$I_\beta \sqsubseteq I_b$$

$$O_b \sqsubseteq O_\beta$$

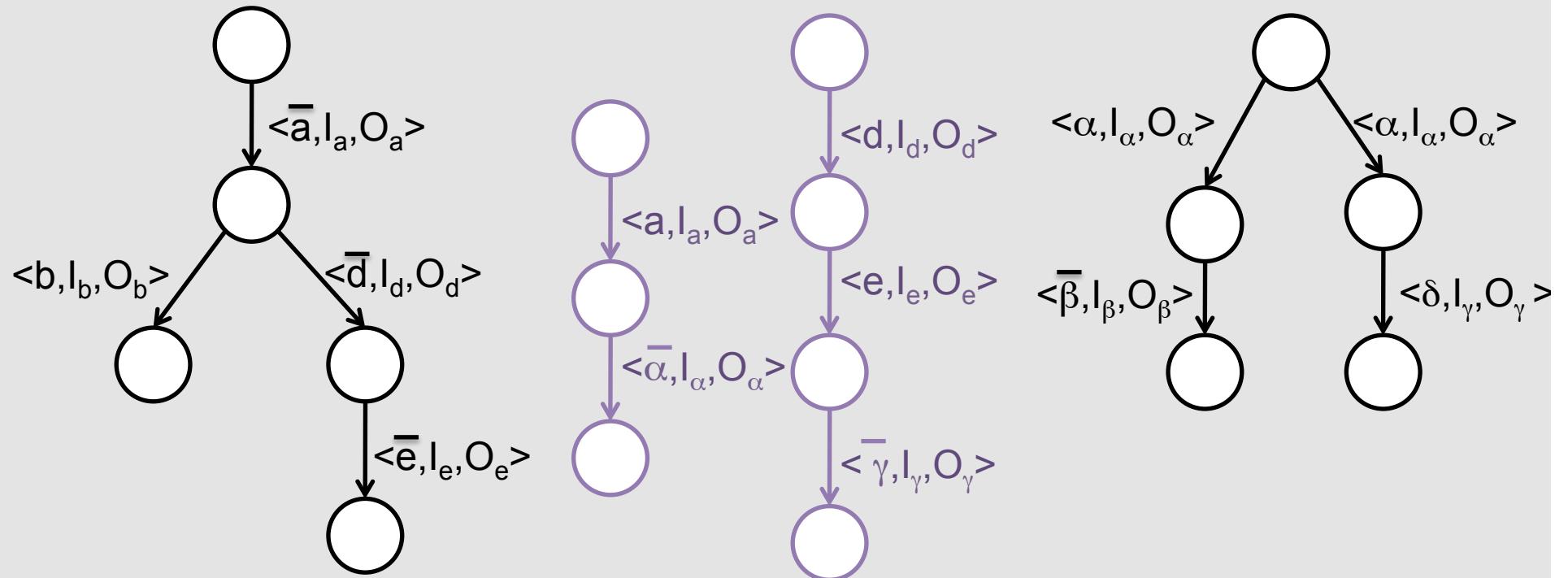
$$\gamma \sqsubseteq d \cup e$$

$$I_d \sqsubseteq I_\gamma$$

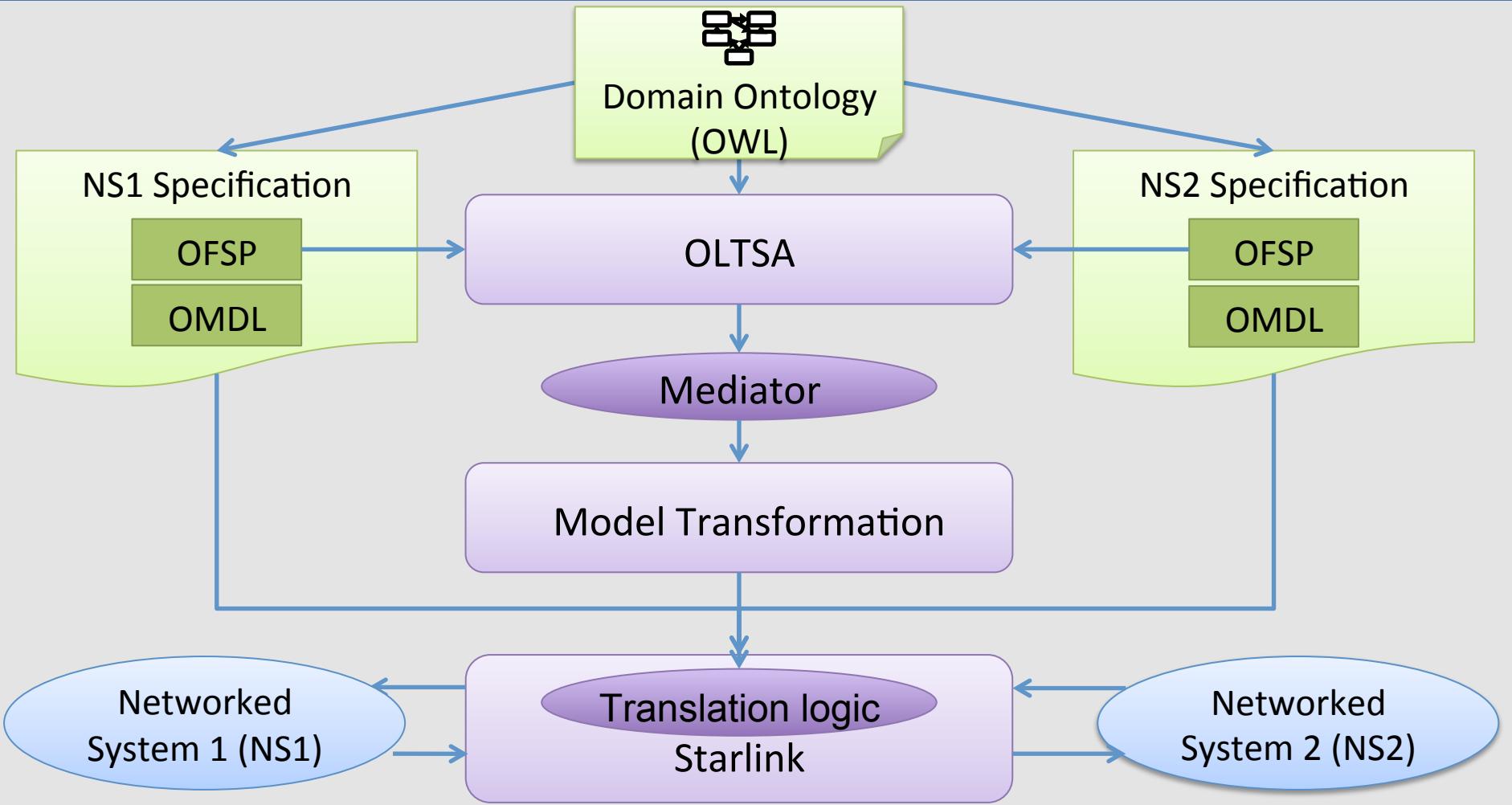
$$I_e \sqsubseteq I_\gamma \cup O_d$$

$$O_\gamma \sqsubseteq O_d \cup O_e$$

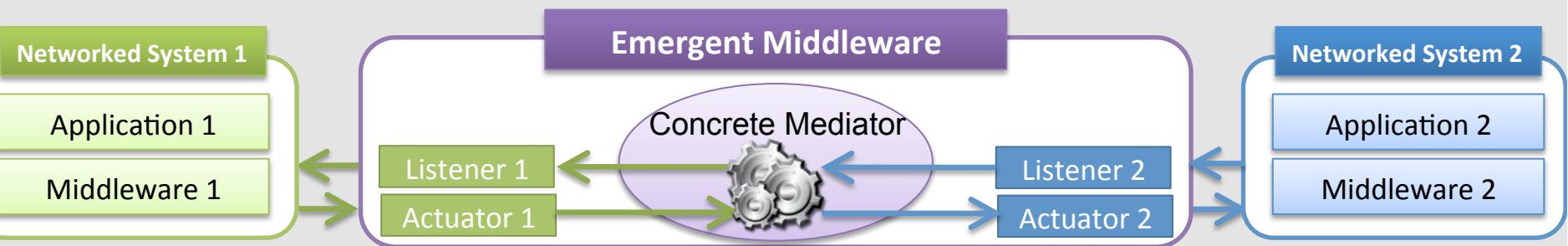
Matching: 1:n mapping



Synthesis: Supporting Tools

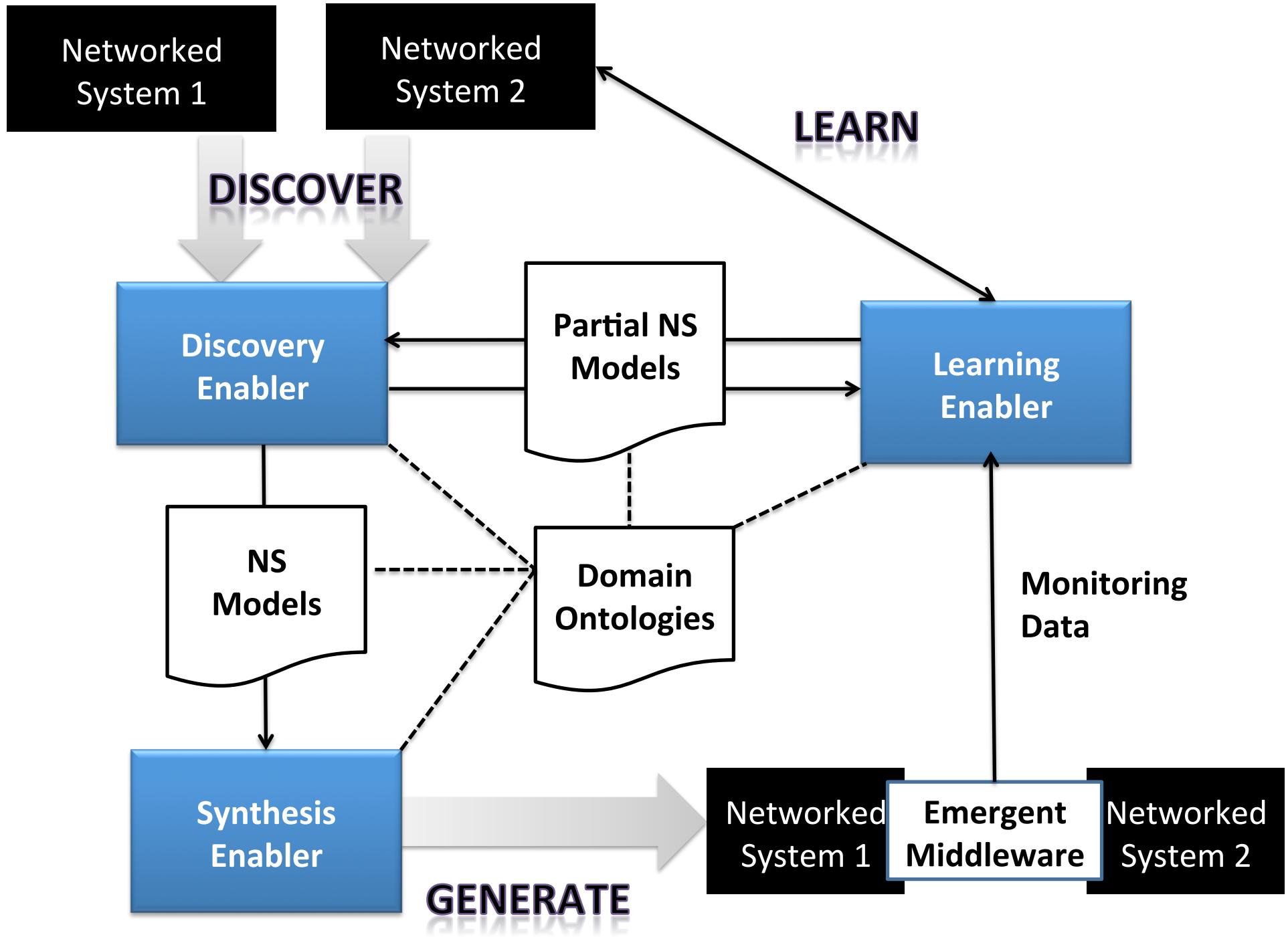


From Abstract Mediator to Concrete Emergent Middleware

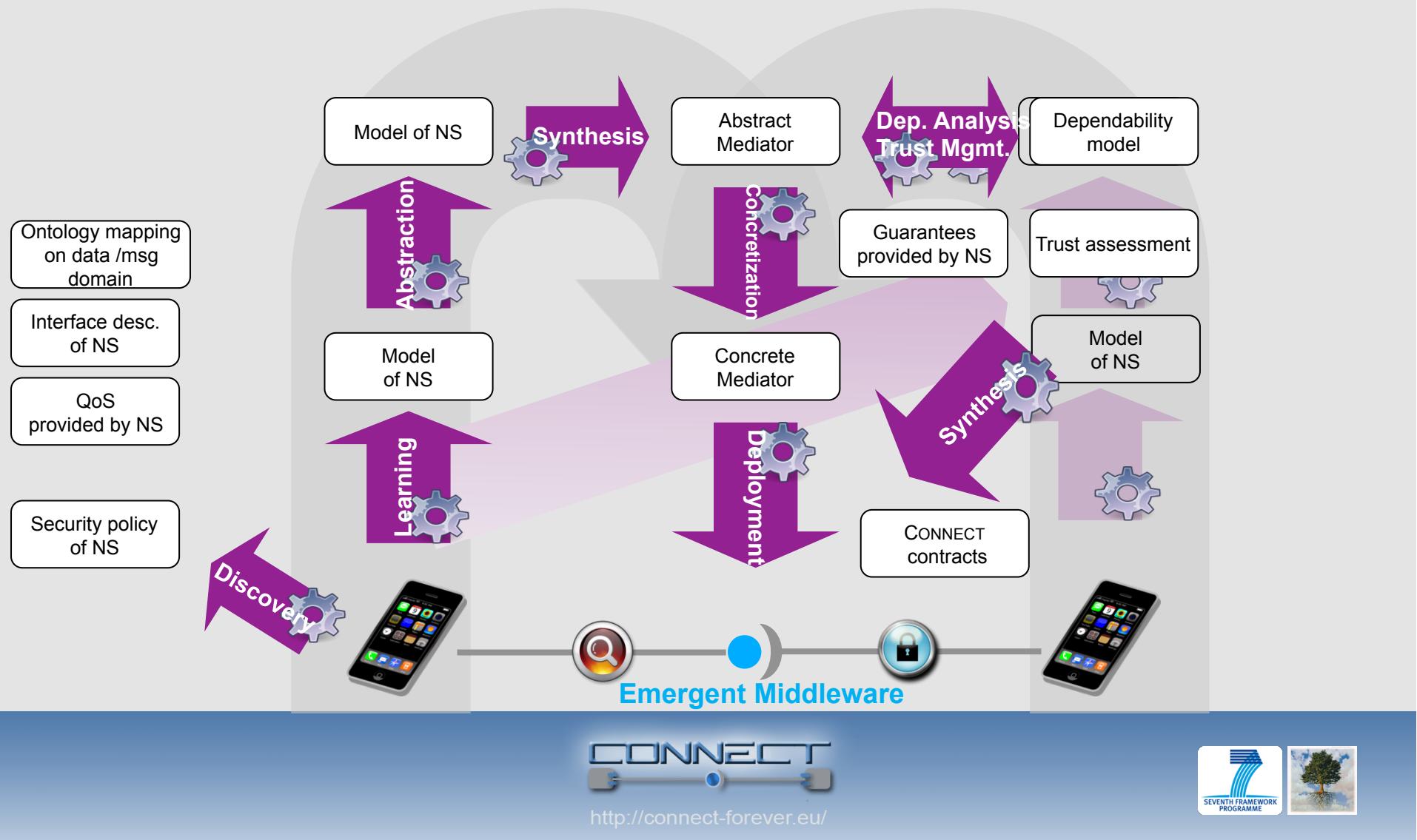


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The CONNECT Enablers in Action



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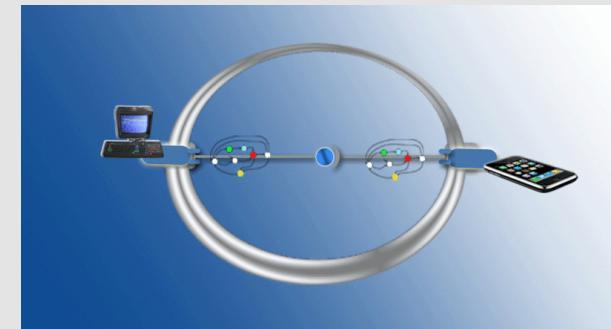
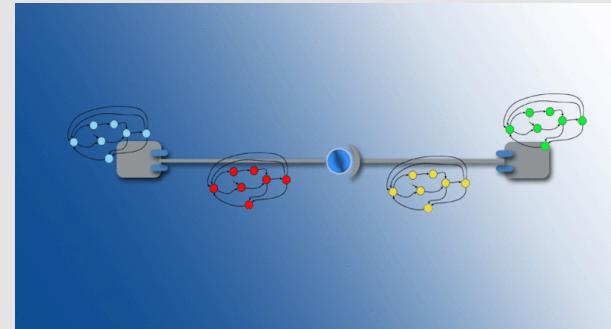
Composing Pervasive Systems

- State-of-the art survey in middleware & data interoperability shows that no current approach meets today's interoperability challenge
- Need for emergent middleware where connectors are synthesized on the fly



Synthesizing CONNECTors for Pervasive Systems

- CONNECTors implementing emergent middleware that **mediate** interactions among pervasive networked systems
- Formalization of interoperability based on matching and mapping relationships between interaction protocols run by networked systems
- Dealing with application- and middleware-layer connectors
- First prototypes of enablers being integrated
- GMES use case being developed



What we have learned so far...

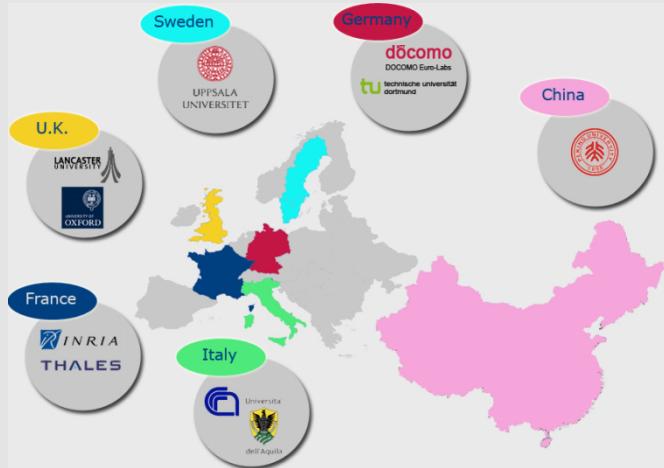
- Middleware research increasingly multi-disciplinary
 - Middleware and Ontology
 - Middleware and Learning
 - Middleware and Abstract models
- Opens several research challenges

To Know more...

- The 11th International School on Formal Methods for the Design of Computer, Communication and Software Systems: Connectors for Eternal Networked Software Systems. LNCS 6659, Springer 2011, ISBN 978-3-642-21454-7.
- <http://connect-forever.eu/publication.html>
- <http://connect-forever.eu/software.html>
- <http://connect-forever.eu/training.html>
- <http://connect-forever.eu/>



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Thank you

Questions?



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