

# Architectural Support for Internet Evolution and Innovation

George N. Rouskas

Department of Computer Science

North Carolina State University

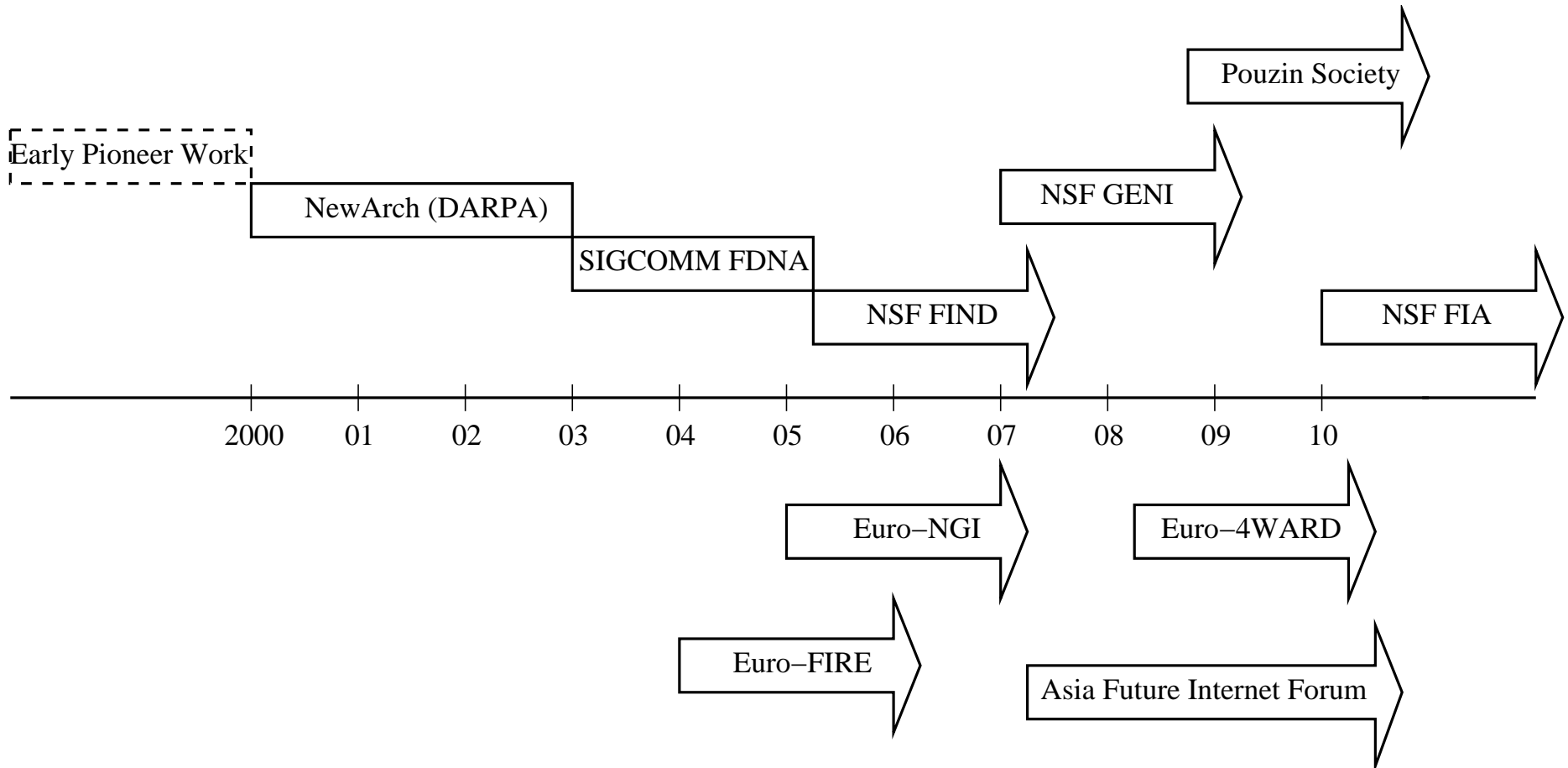
<http://net-silos.net/>

Joint work with: Ilia Baldine (RENCI), Rudra Dutta (NCSU),  
Anjing Wang (Ericsson), Mohan Iyer (Oracle)

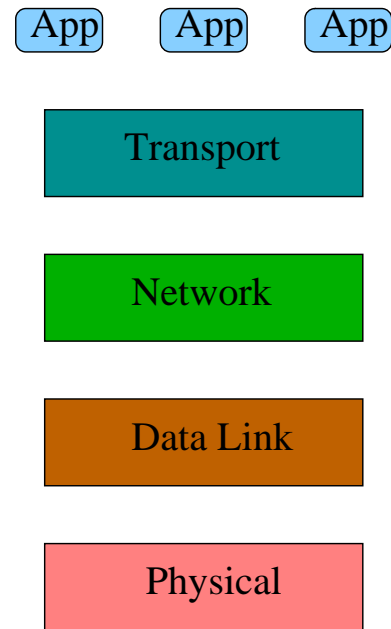
# Outline

- **Motivation:** Challenges with Internet Architecture
- **SILO:** A Meta-Design Framework
- **SILO as Research Tool:** Cross-Layer Experimentation
- Summary

# In Search of Next Generation Internet



# Challenges with Current Architecture



1. **Evolution:** function-heavy protocols with built-in assumptions
2. **High barrier to entry:** for new data transfer protocols
3. **Cross-layer design:** lack of inter-layer interactions/controls

# Accommodating New Functionality

- Deploy half-layer solutions (MPLS, IPSec)
  - layers become markers for vague functional boundaries
- Adapt existing implementation to new situations
  - TCP over wireless/large bw/delay product networks
- Implement own UDP-like data transfer
  - no reuse or kernel optimizations
- Abandon the old: new implementations for sensor networks
  - Internet balkanization

# Our View

- Internet architecture houses an effective design
- **But:** it is not itself effective in enabling evolution
- New architecture must be designed for **adaptability/evolvability**
- New architecture must **preserve/generalize** layering
- SILO objective: **design for change**

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# What is Architecture?

- Fundamental elements/principles *vs.* design decisions
- *Diverse points of view* → FIND projects target: addressing, naming, routing, protocol architecture, security, management, economics, communication technologies (wireless, optical), . . .
- Our definition:

*it is precisely the characteristics of the system that does not change itself, but provides a framework within which the system design can change and evolve*

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The goal is not to design the “next” system, or the “best next” system, but rather a system that can sustain continuing change

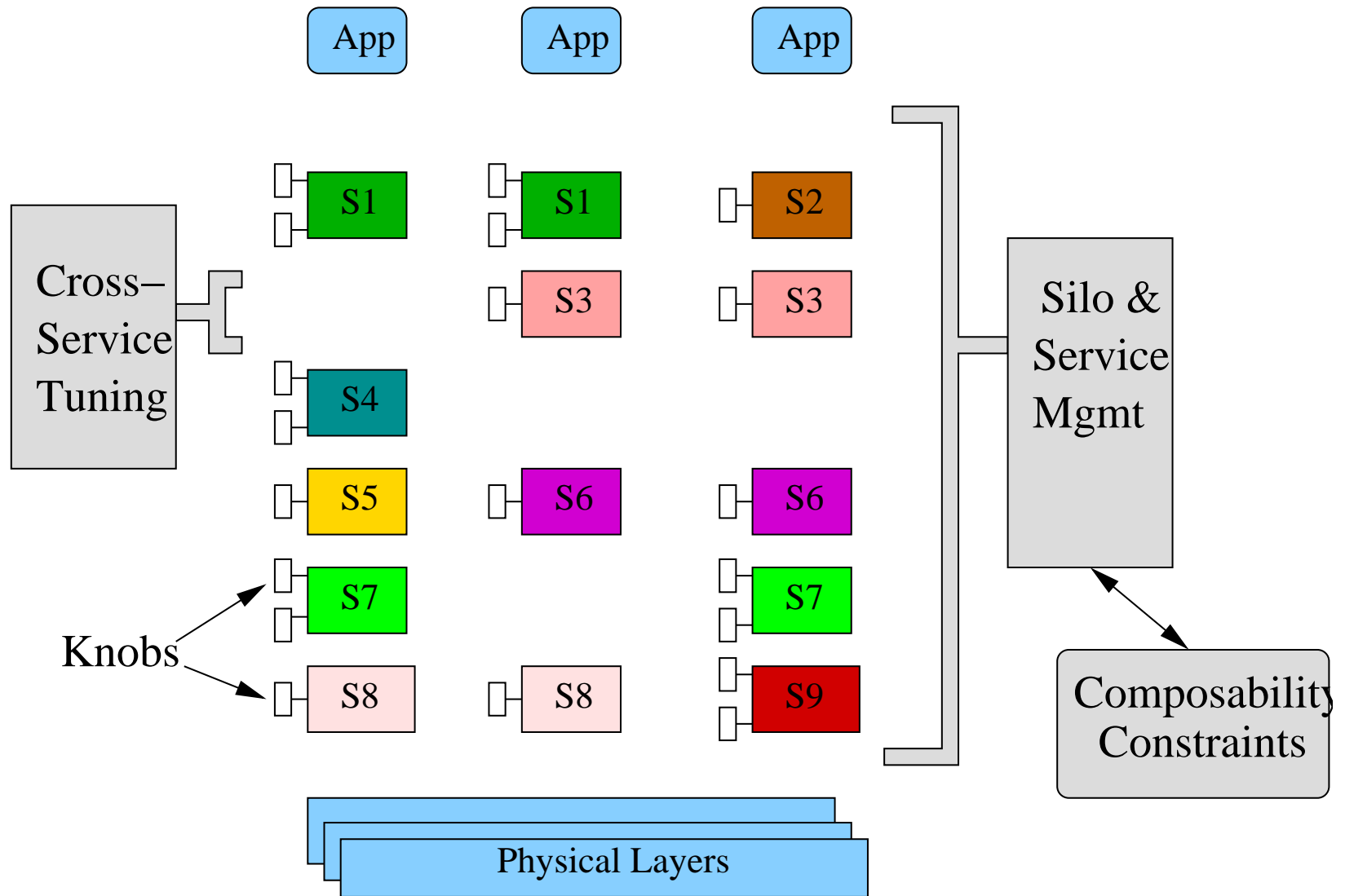
# SILO Architecture Highlights

- **Building Blocks:** services of fine-grain functionality
- **Design Principles:**
  1. Generalize traditional layer stack
  2. Enable inter-layer interactions:
    - **knobs:** explicit control interfaces
  3. Design for change:
    - facilitate introduction of new services
  4. Separate **control** from **data** functions

# Generalization of Layering

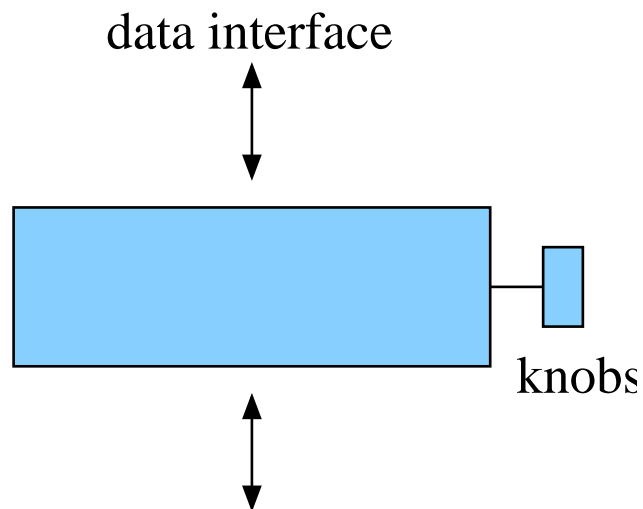
- **Silo:** vertical composition of services  
→ preserves layering principle
- **Per-flow** instantiation of silos  
→ introduces flexibility and customization
- **Decoupling** of layers and services  
→ services introduced at point in stack where necessary

# Silos: Generalized Protocol Stacks



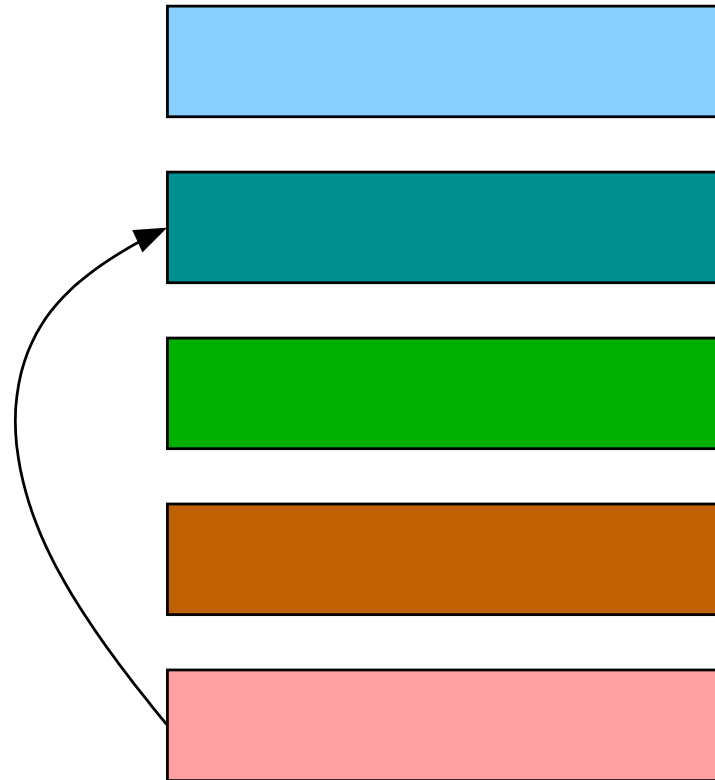
# Inter-Layer Interactions (1)

- **Knobs:** explicit control interfaces
  - adjustable parameters specific to functionality of service
  - enable info exchange among services
- Algorithms may optimize jointly the behavior of services in a silo



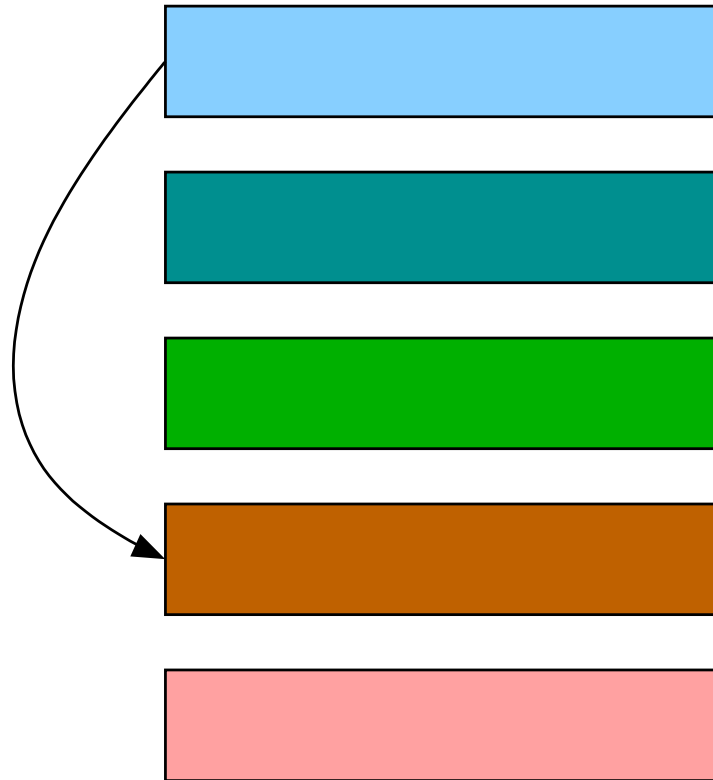
# Inter-Layer Interactions (2)

Upward information passing



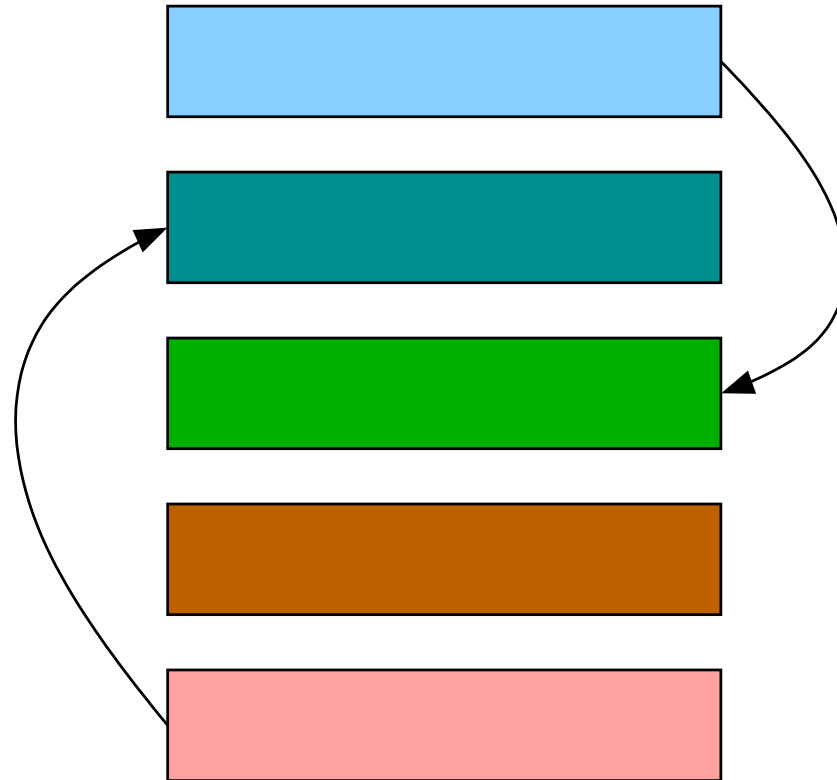
# Inter-Layer Interactions (2)

Downward information passing



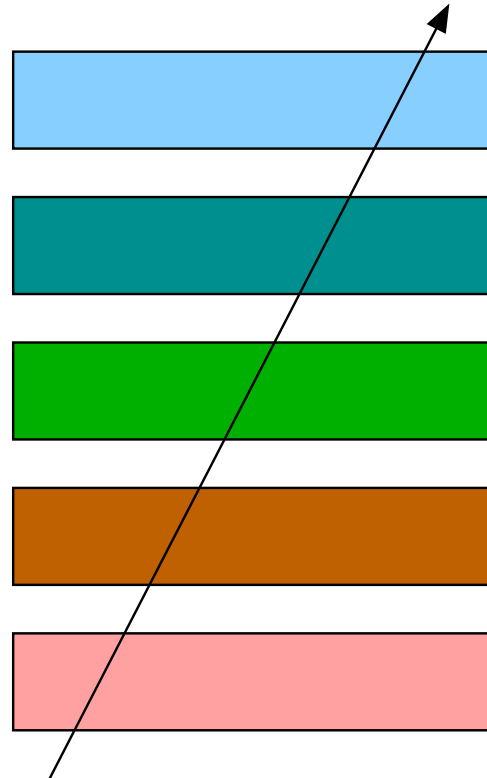
# Inter-Layer Interactions (2)

Up-and-down information passing



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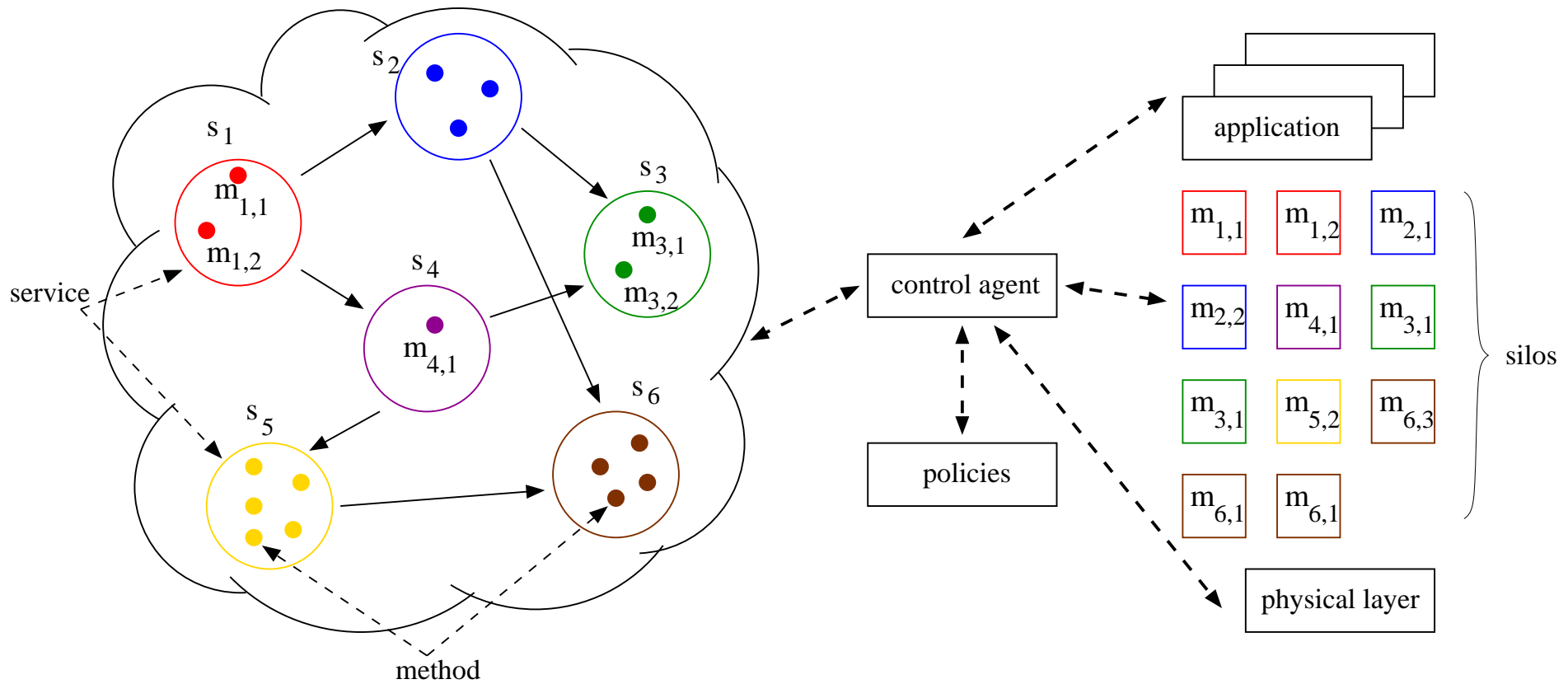
Silo-wide optimization/calibration



# Design for Change

- Architecture **does not dictate** services to be implemented
- Provide mechanisms to:
  - introduce new services
  - compose services into silos
- **Ontology** of services: describes
  - service semantics → function, data/control interfaces
  - relationship among services → relative ordering constraints

# Ontology – Networking Knowledge

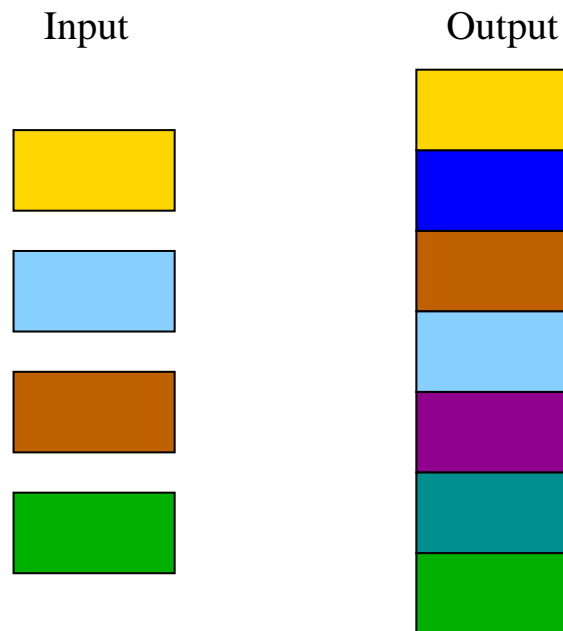


# Service Composition

- Constraints on composing services **A** and **B**:
  - A requires B
  - A forbids B
  - A must be above (below) B
  - A must be immediately above (below) B
  - Negations, AND, OR
- Minimal set:
  - Requires, Above, ImmAbove, NotImmAbove
- All pairwise condition sets realizable
  - Forbids = (A above B) AND (B above A)
  - Above = NOT Below

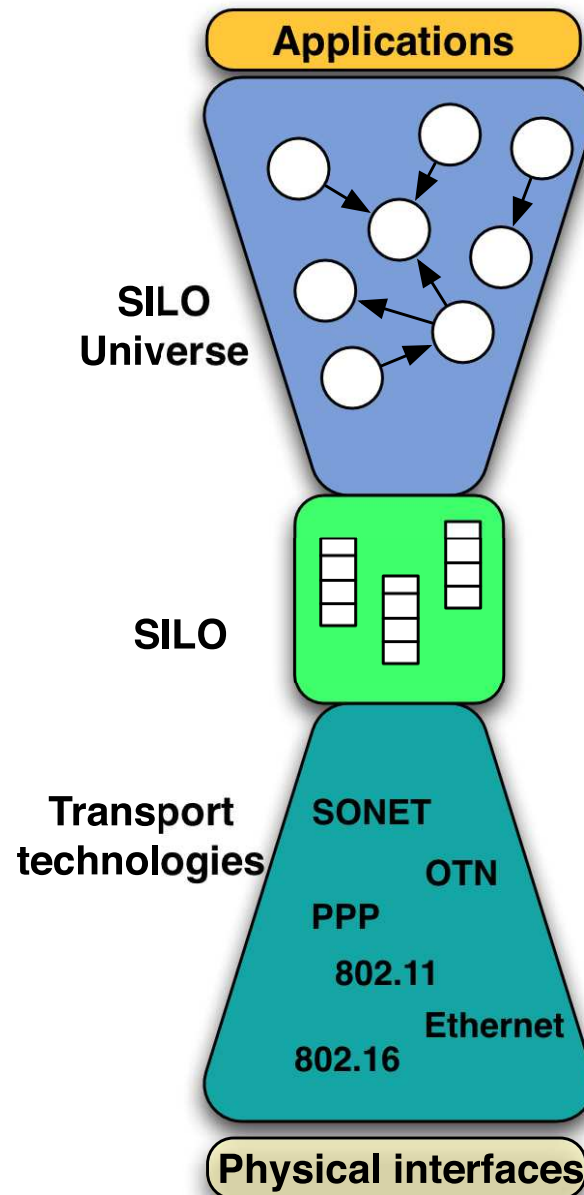
# Service Composition Problem

- Given: a set of essential services ← application
- Obtain a valid ordering of these and additional services
  - or, identify conflicts with constraints
- Simple composition algorithm implemented
- Ongoing research in formalizing the problem

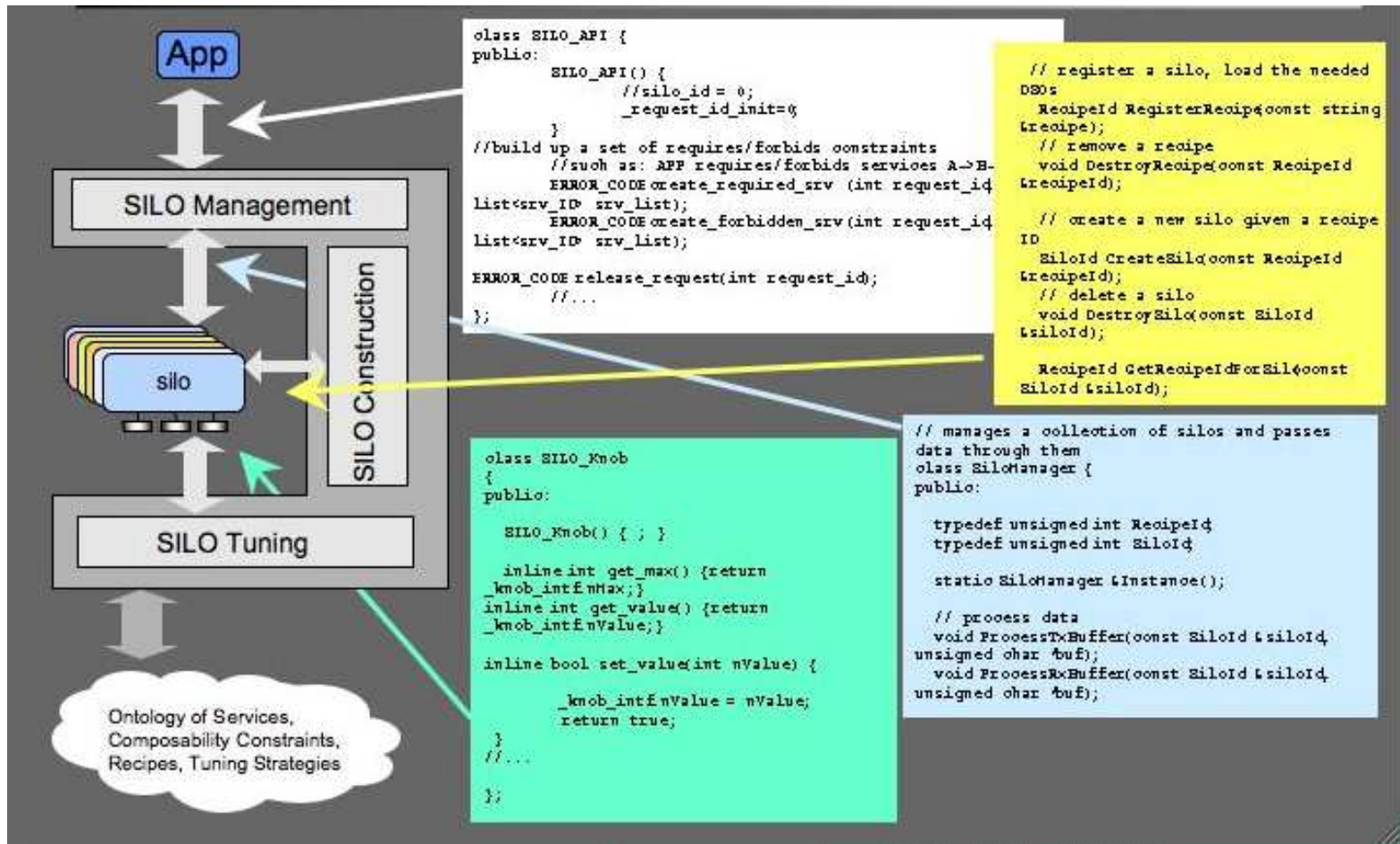


# The SILO Hourglass

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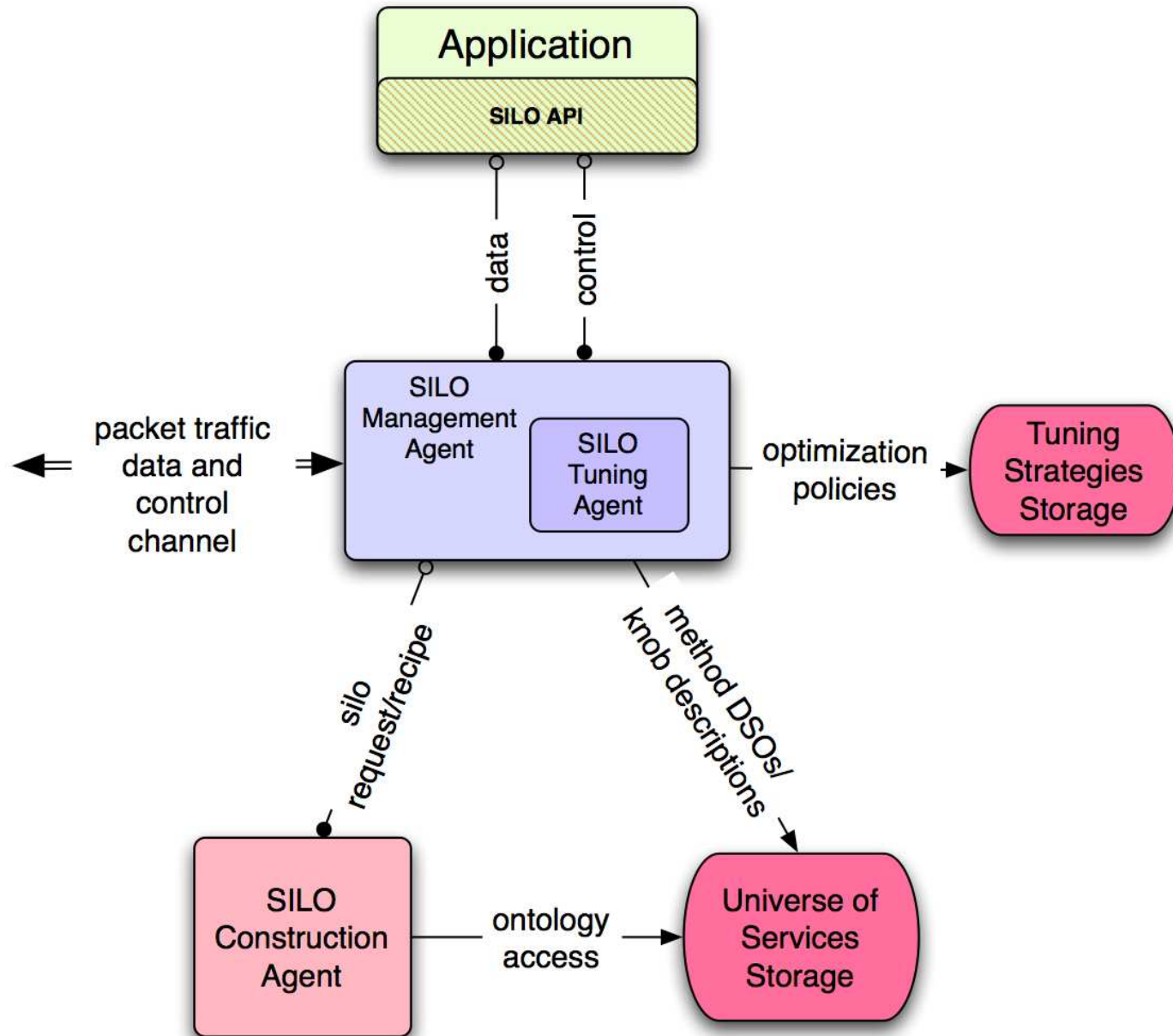


# SILO Software Prototype

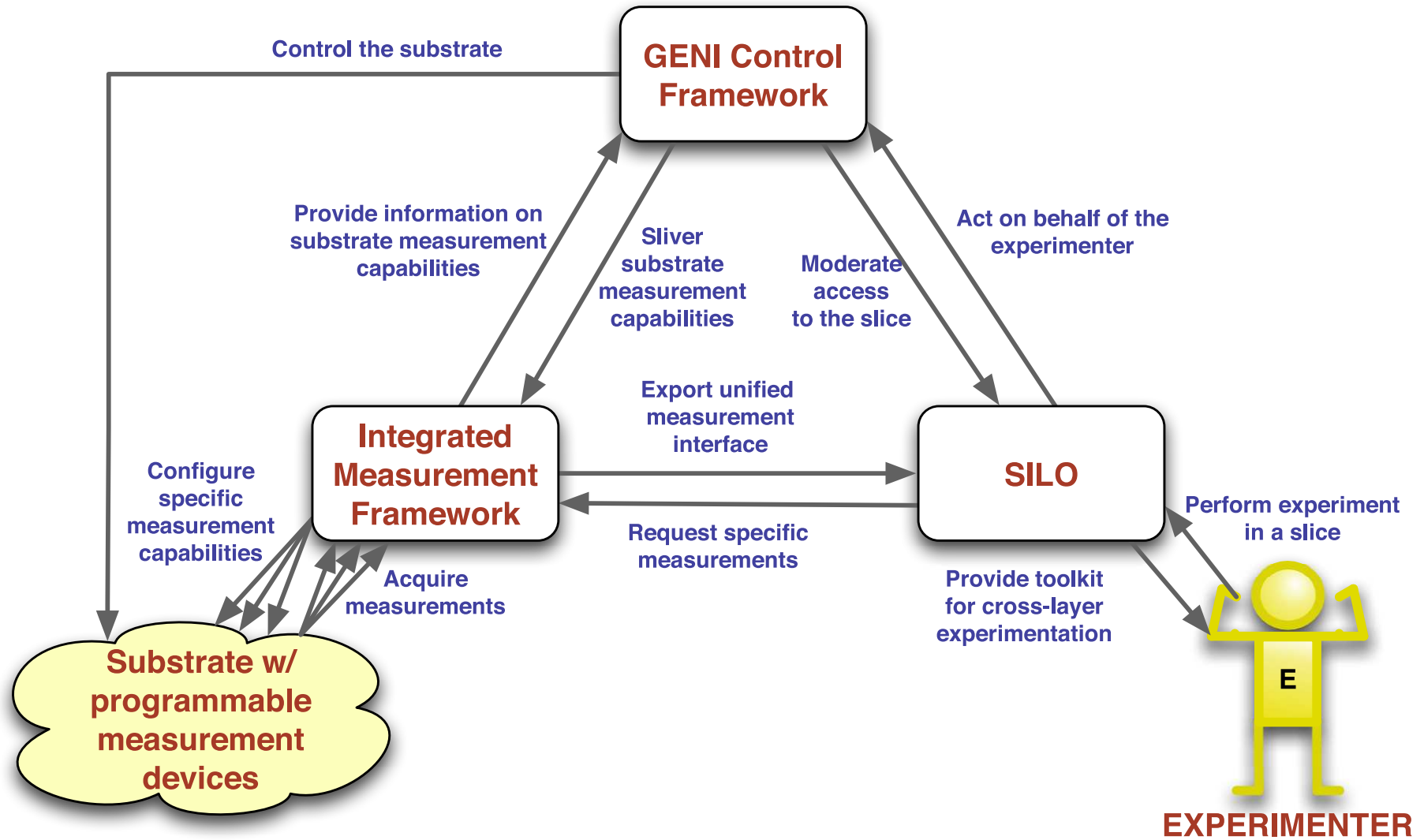


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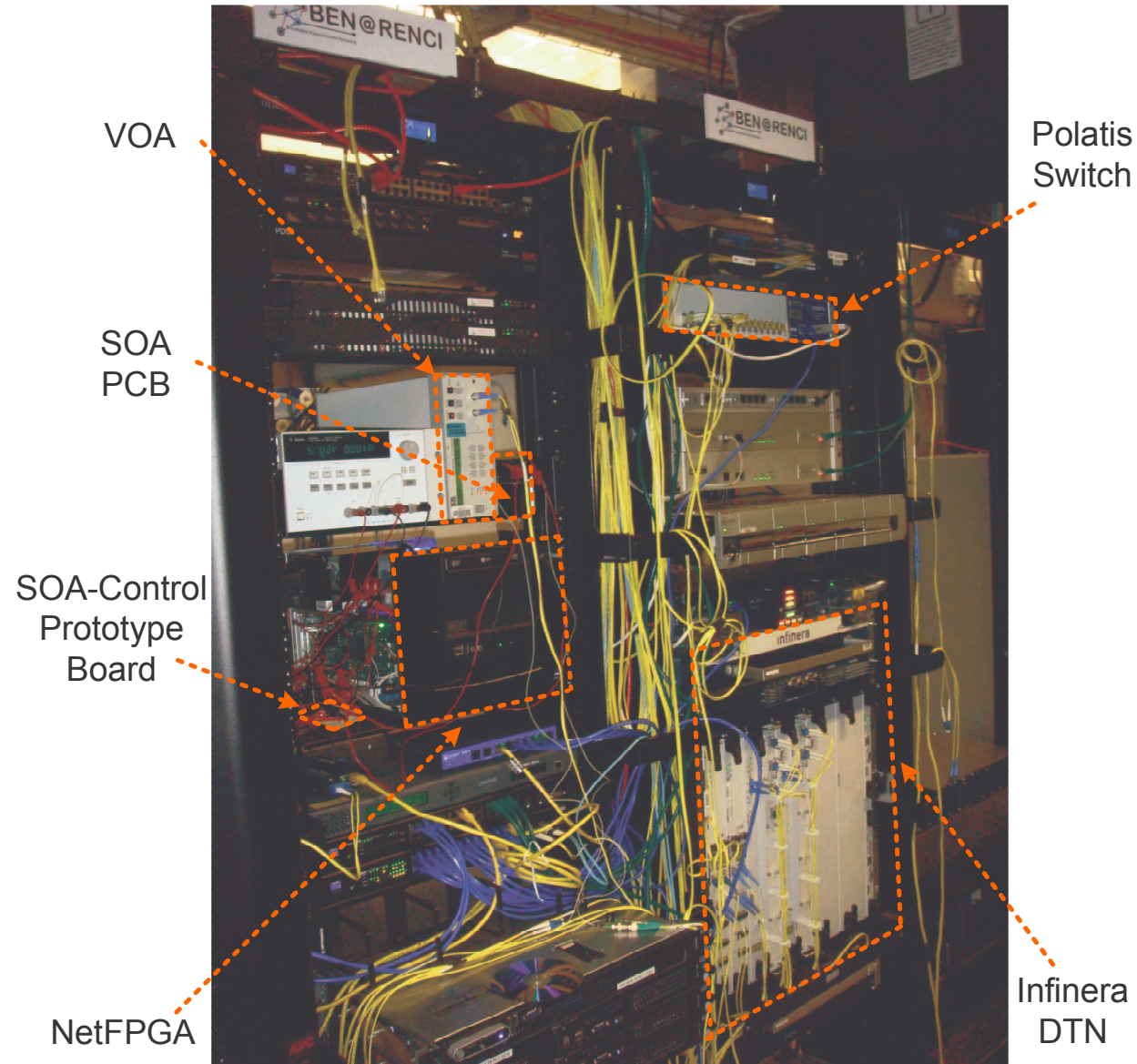
# Prototype Architecture



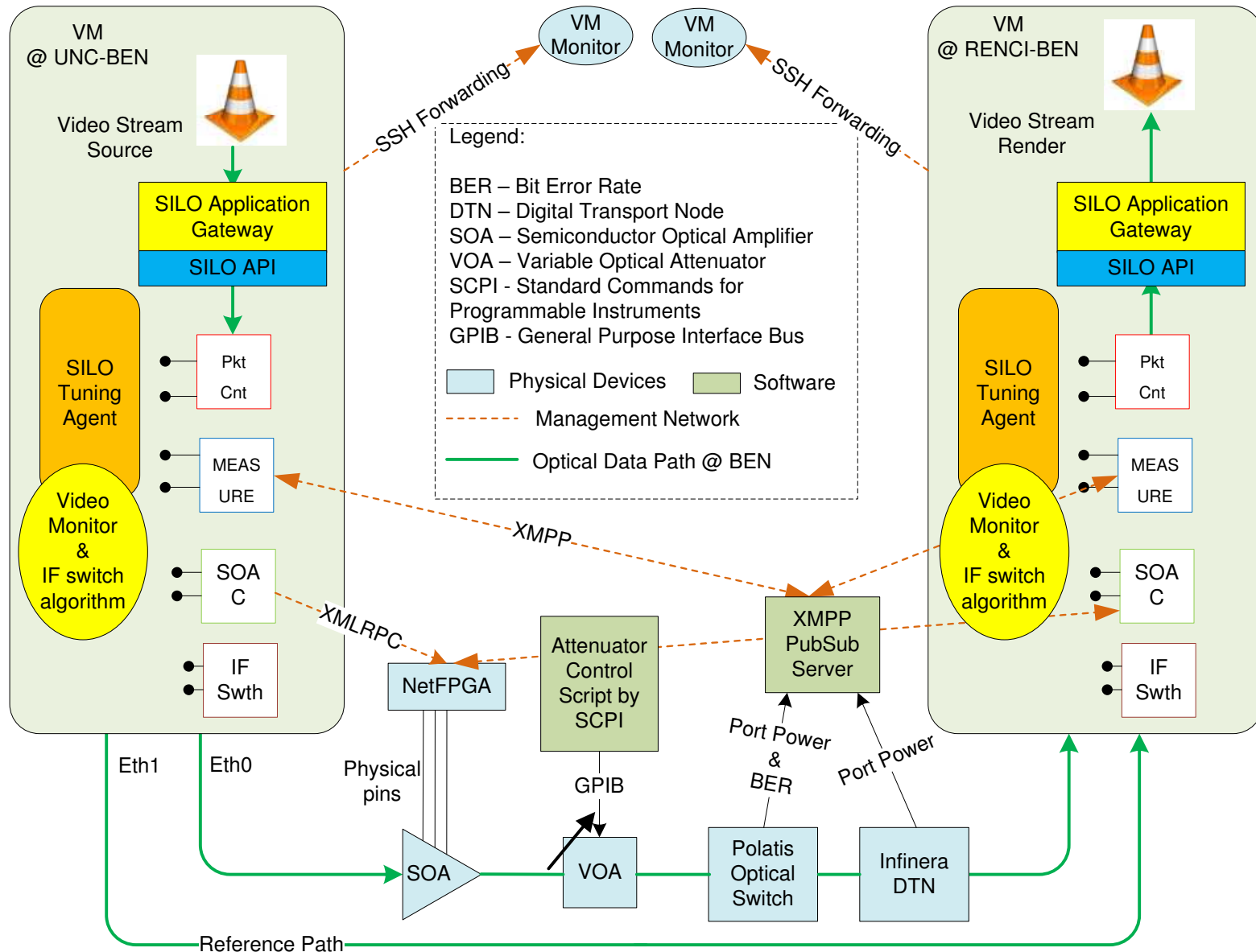
# SILO As a Research Tool



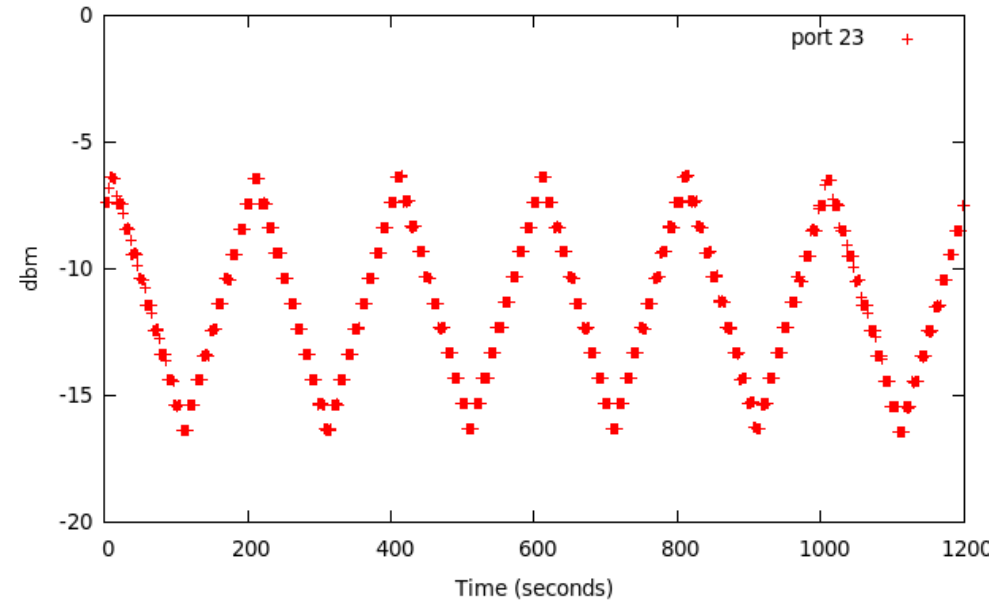
# IMF Physical Infrastructure



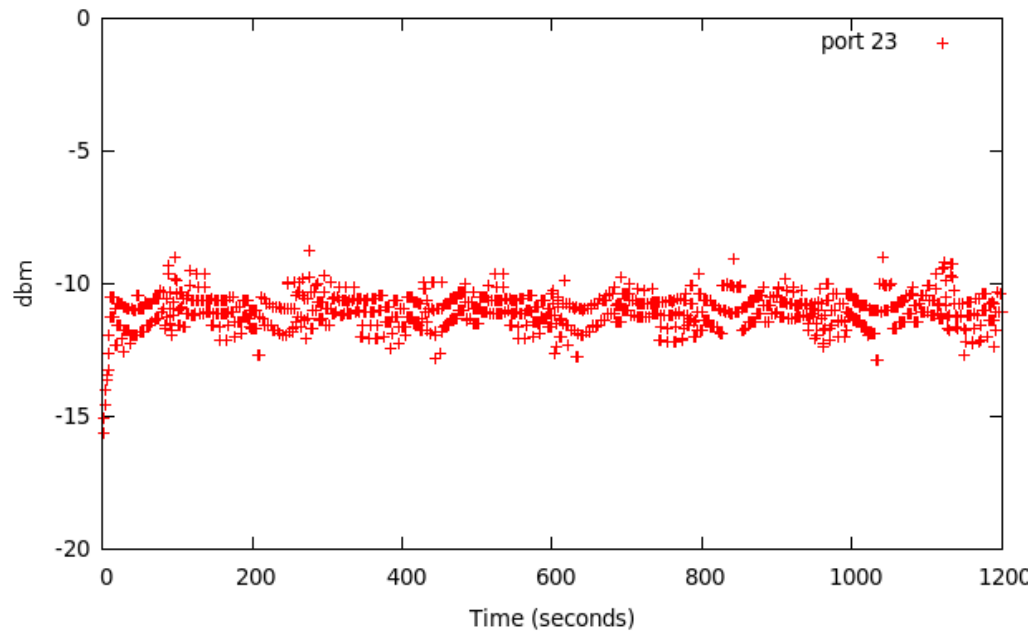
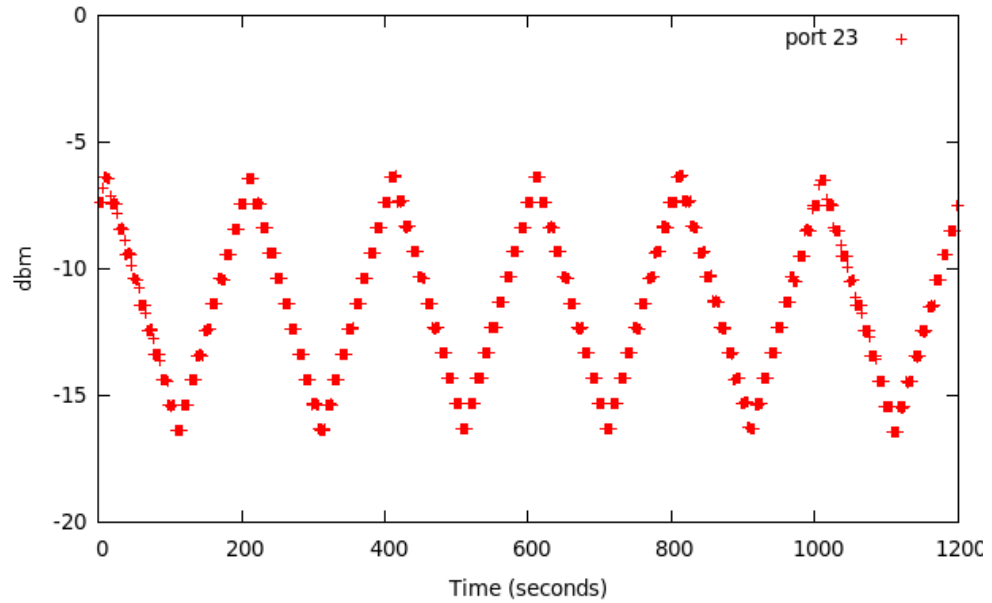
# IMF Cross-Service Demo



# IMF Demo – Results



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# Summary

- Vision – enable flexibility, evolution: “design for change”
  - fine-grain, reusable services, explicit control interface
    - enables experimentation, flexibility, community of innovation
  - per-flow service composition (silos)
    - ease of evolution, policies
- Framework – provide architectural support to vision:
  - constrained composition
  - commoditize cross-layer interaction / optimization

# Ongoing Efforts

- New research directions
  - silos in the core and scalability
  - policy enforcement through composition constraints
  - (generalized) virtualization as a service
- Extend the prototype
  - portfolio of reusable services
  - optical testbed deployment → breakable experimental net (BEN)

# Upcoming Book

