NC STATE UNIVERSITY

# Architectural Support for Internet Evolution and Innovation

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http://net-silos.net/

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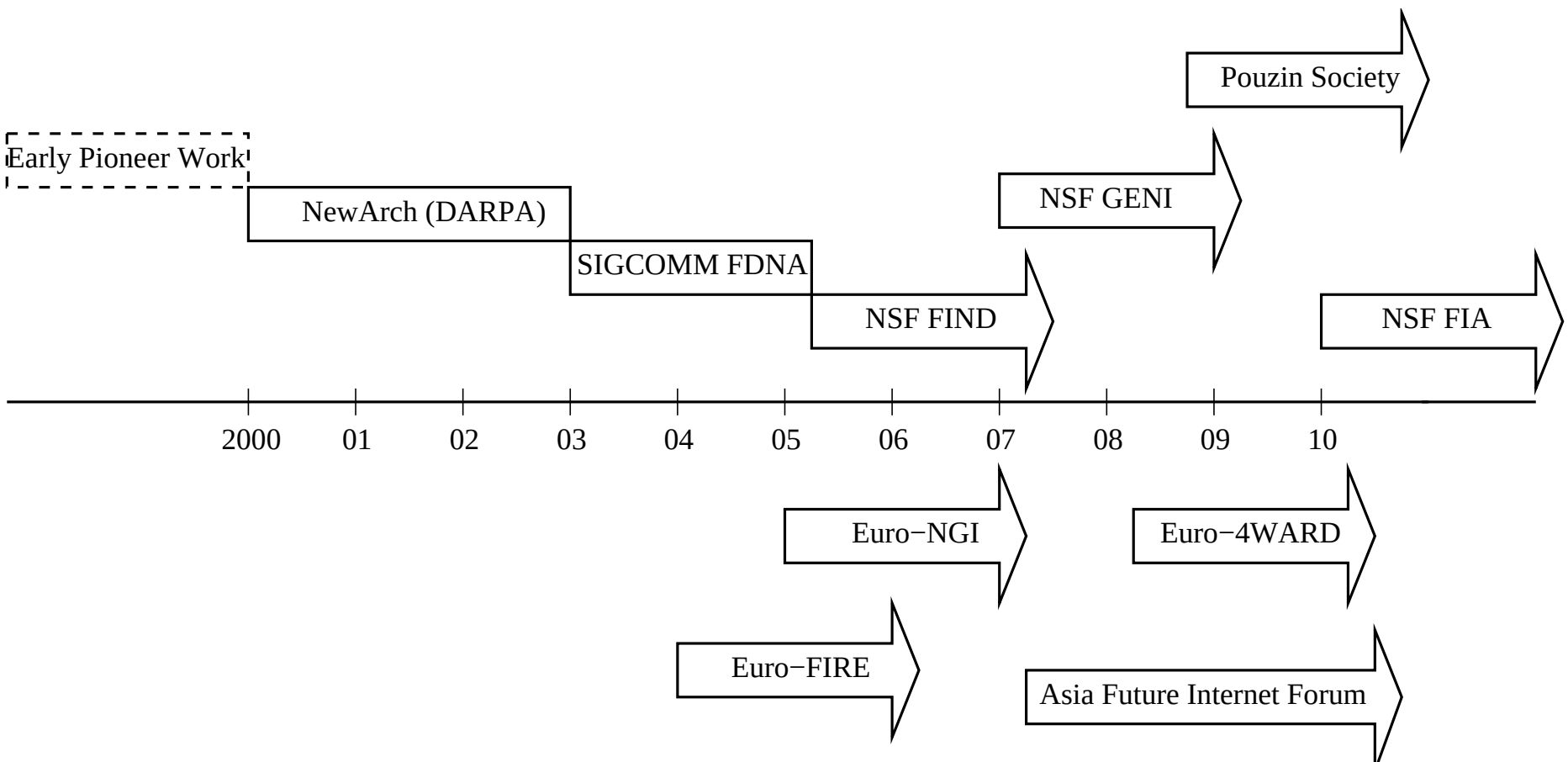
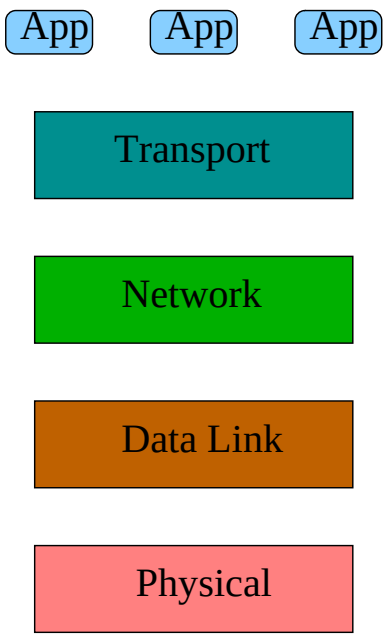
# Outline

- 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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- Diverse points of view $\longrightarrow$ FIND projects target: addressing, naming, routing, protocol architecture, security, management, economics, communication technologies (wireless, optical), $\cdots$
- 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

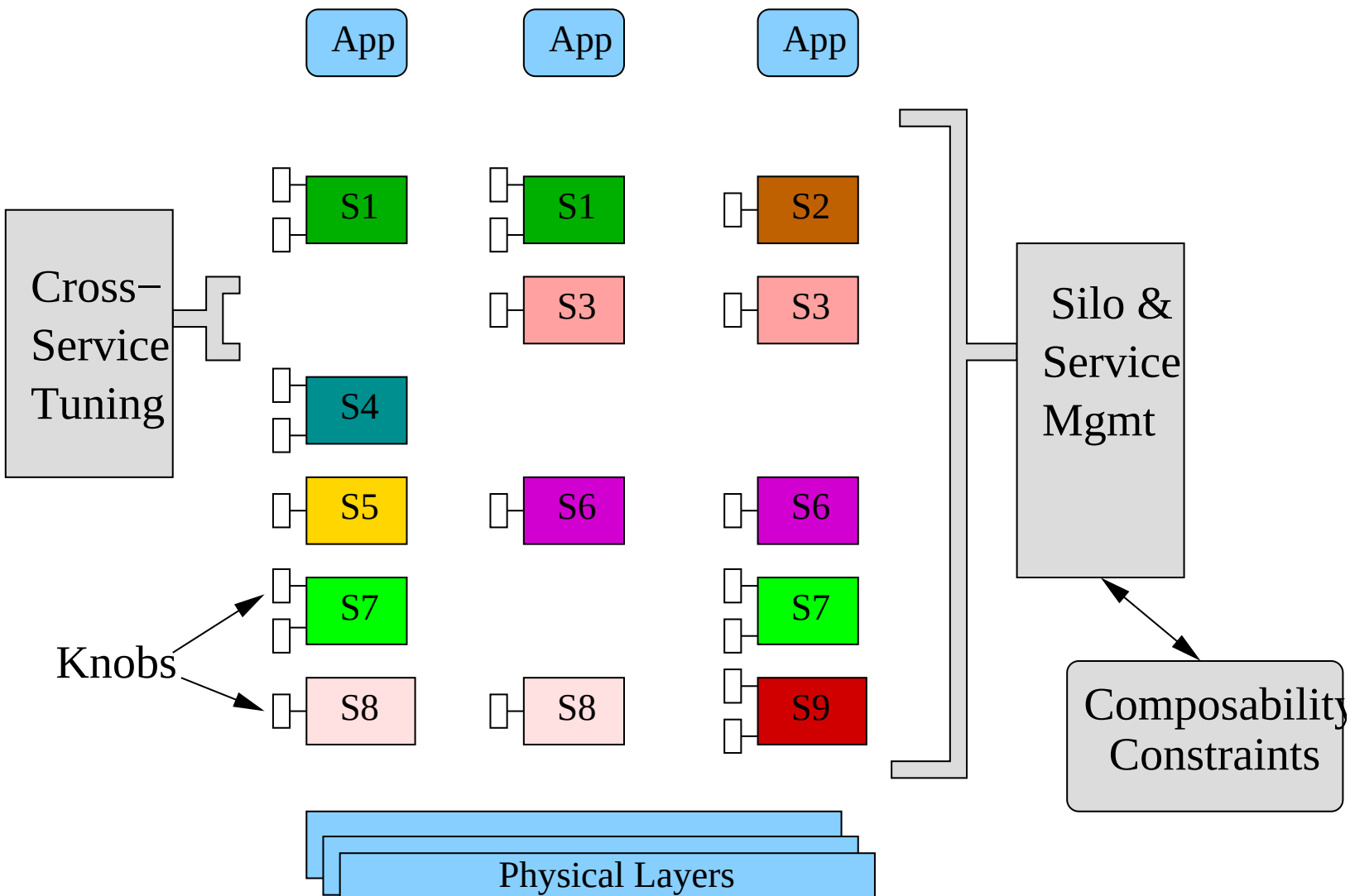
# SILO Architecture Highlights

- 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

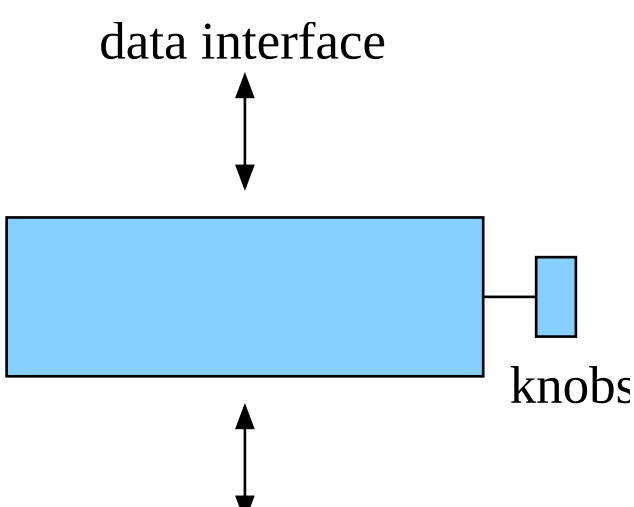
- Silo: vertical composition of services
  → preserves layering principle
- Per-flow instantiation of silos
  → introduces flexibility and customization
- Decoupling of layers and services
  → services introduced at point in stack where necessary

# Silos: Generalized Protocol Stacks



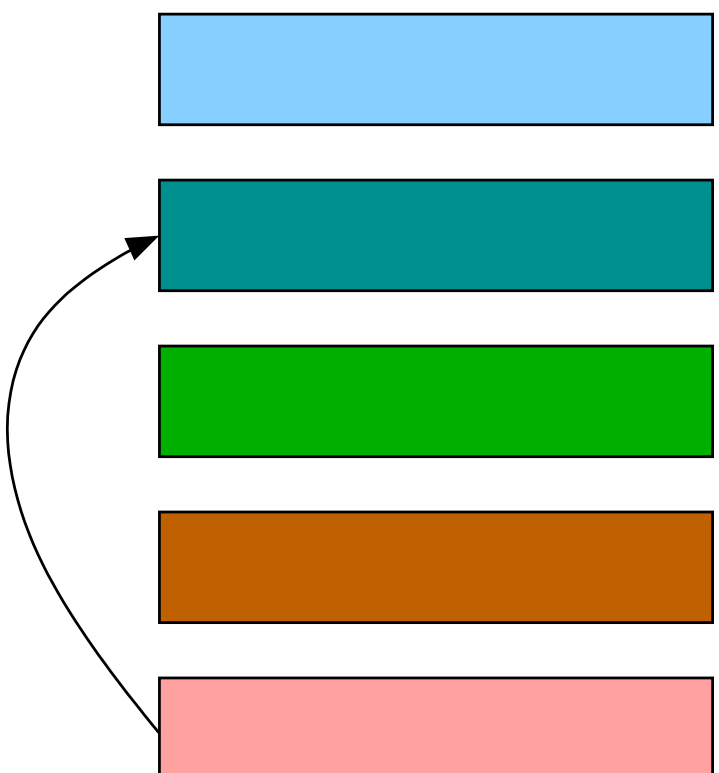
# Inter-Layer Interactions (1)

- 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



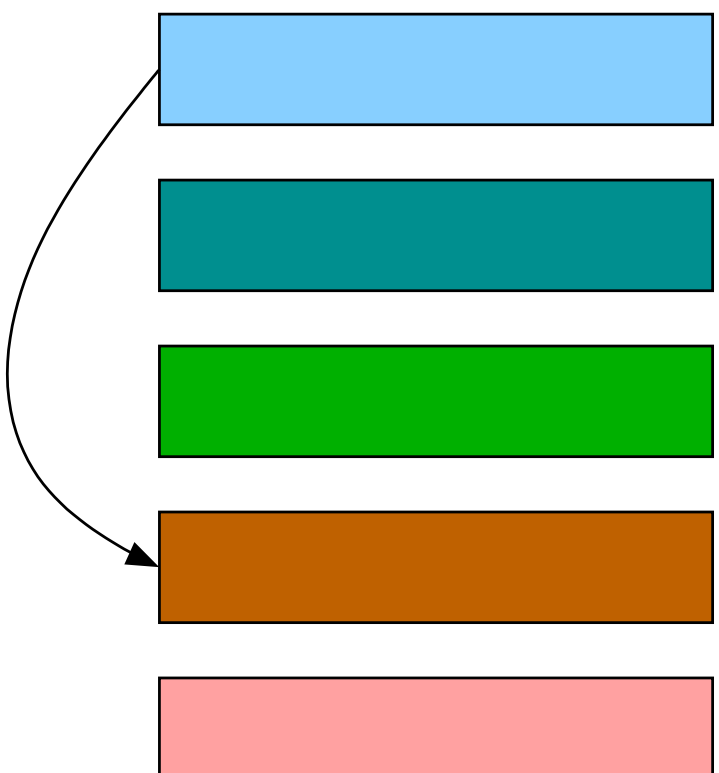
# Inter-Layer Interactions (2)

## Upward information passing



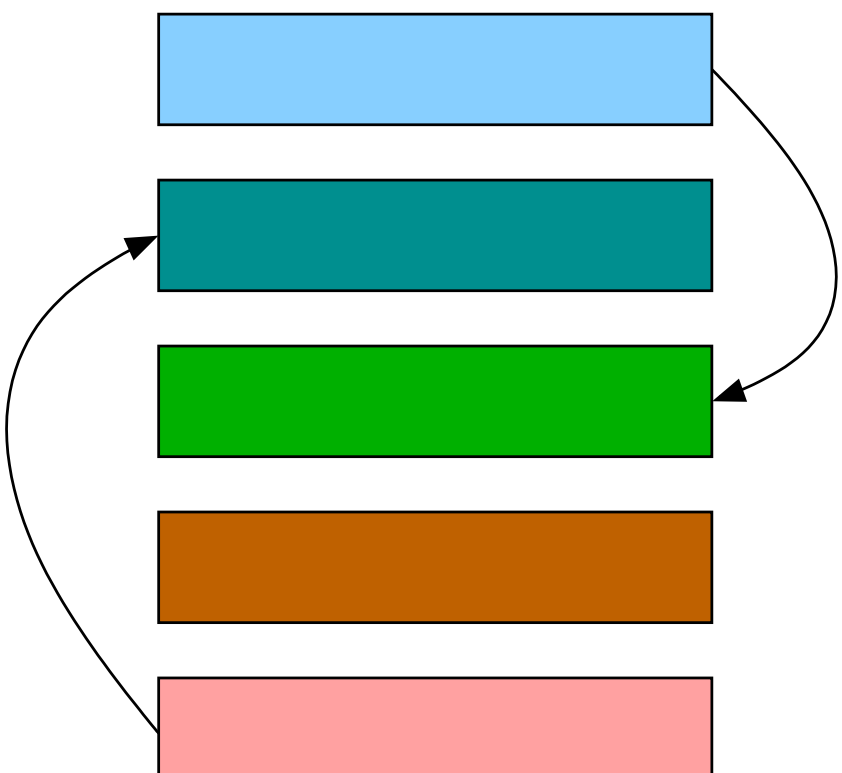
# Inter-Layer Interactions (2)

## Downward information passing



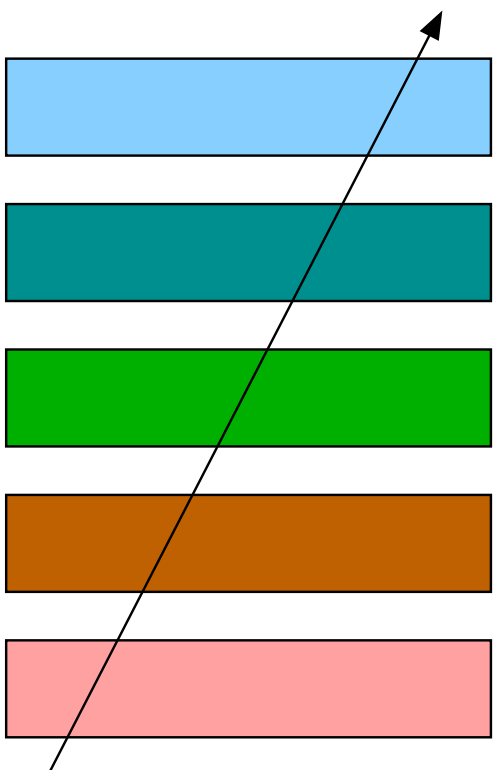
# Inter-Layer Interactions (2)

## Up-and-down information passing



# Inter-Layer Interactions (2)

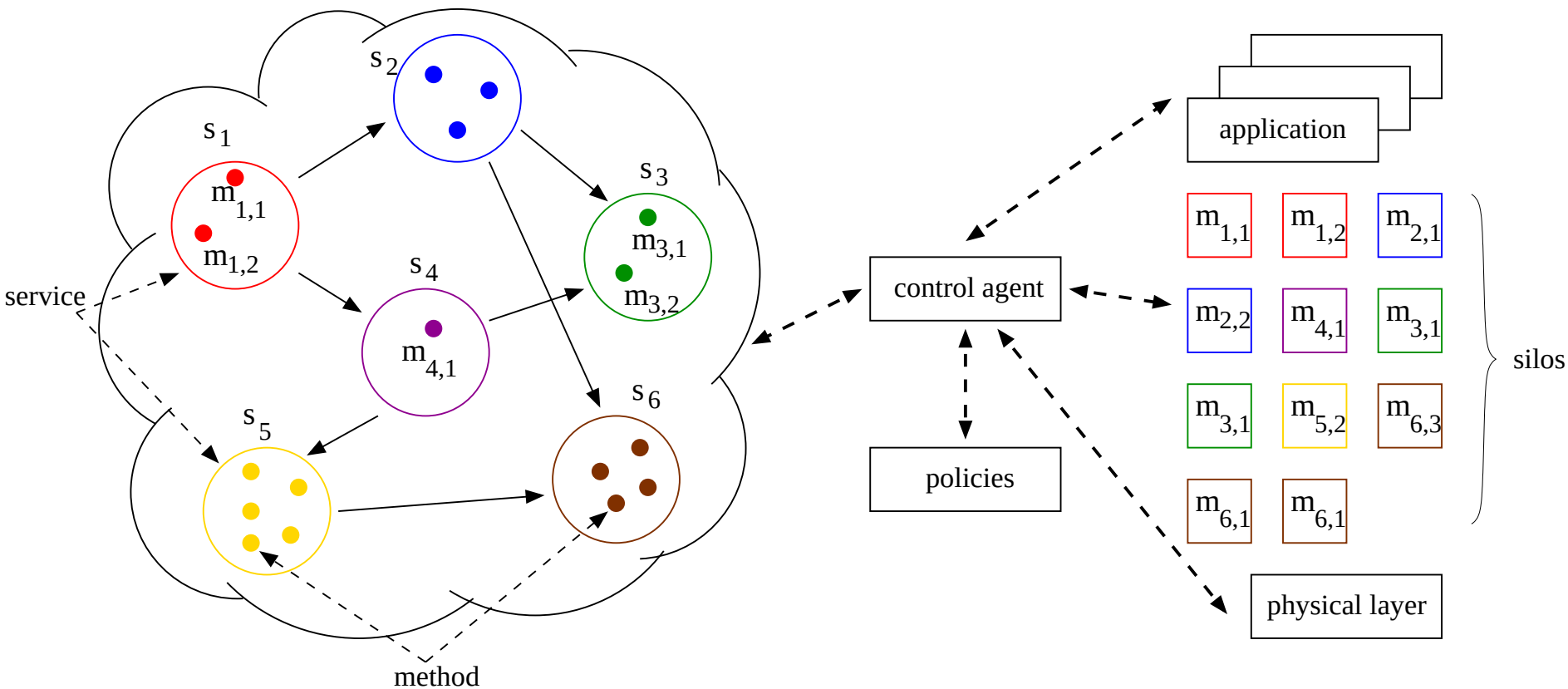
Silo-wide optimization/calibration



# 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 $\longrightarrow$ function, data/control interfaces
  - relationship among services $\longrightarrow$ relative ordering constraints

# Ontology – Networking Knowledge

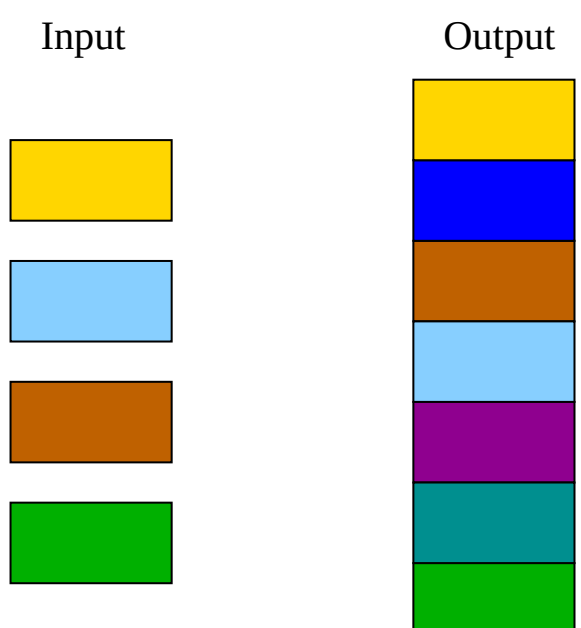


# Service Composition

- 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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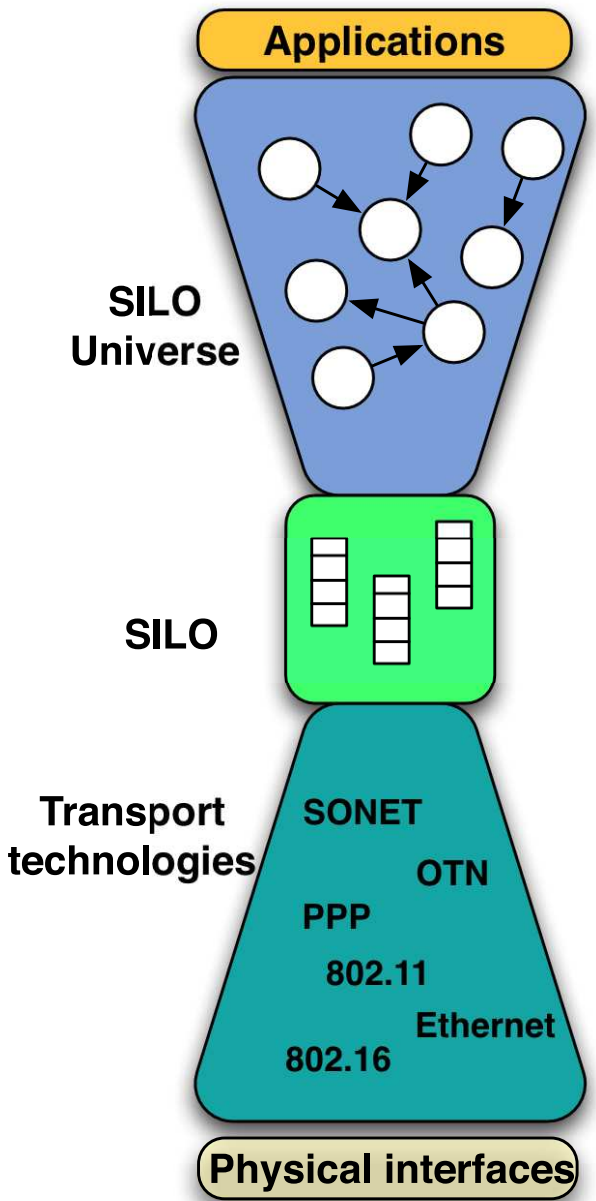
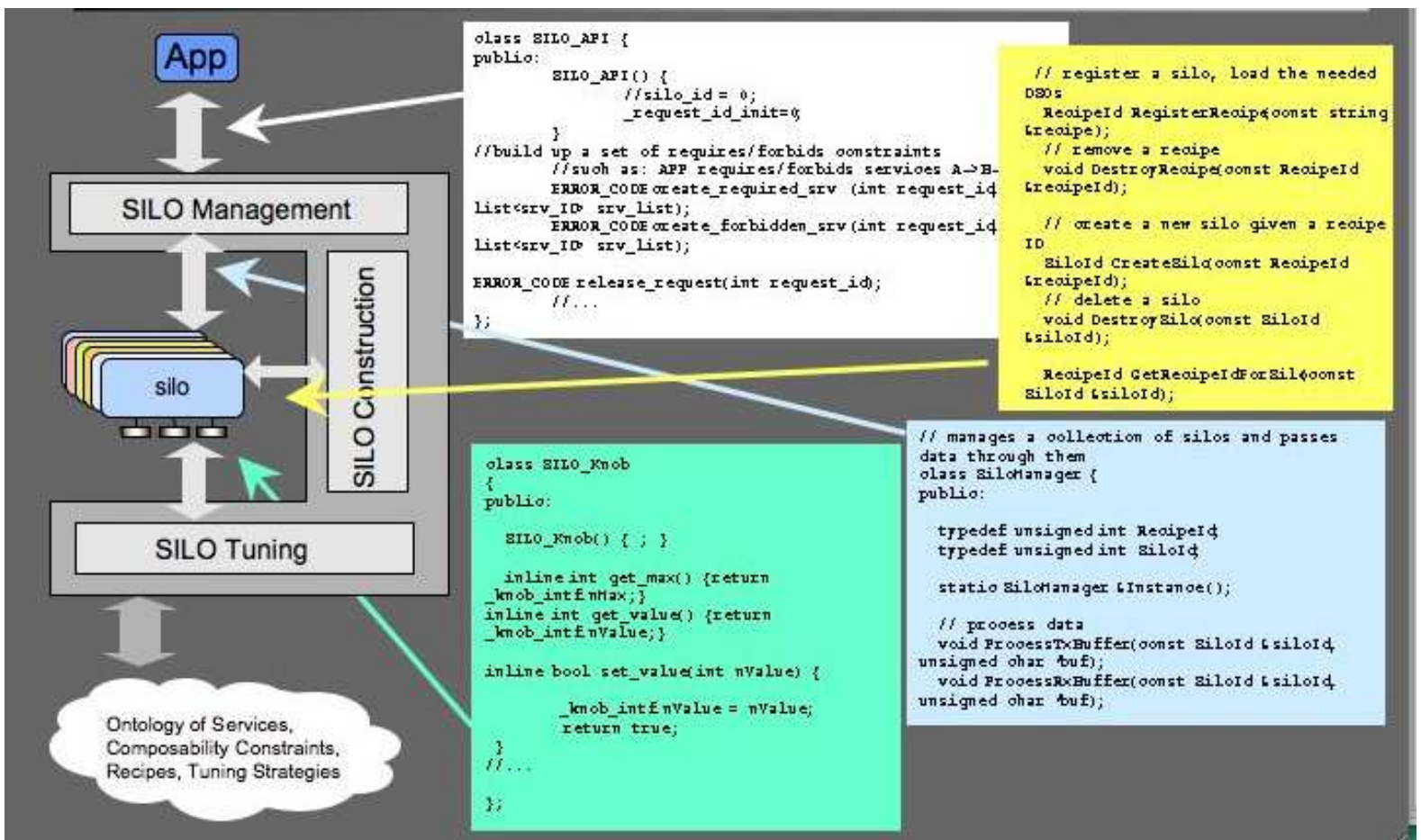


# SILO Software Prototype

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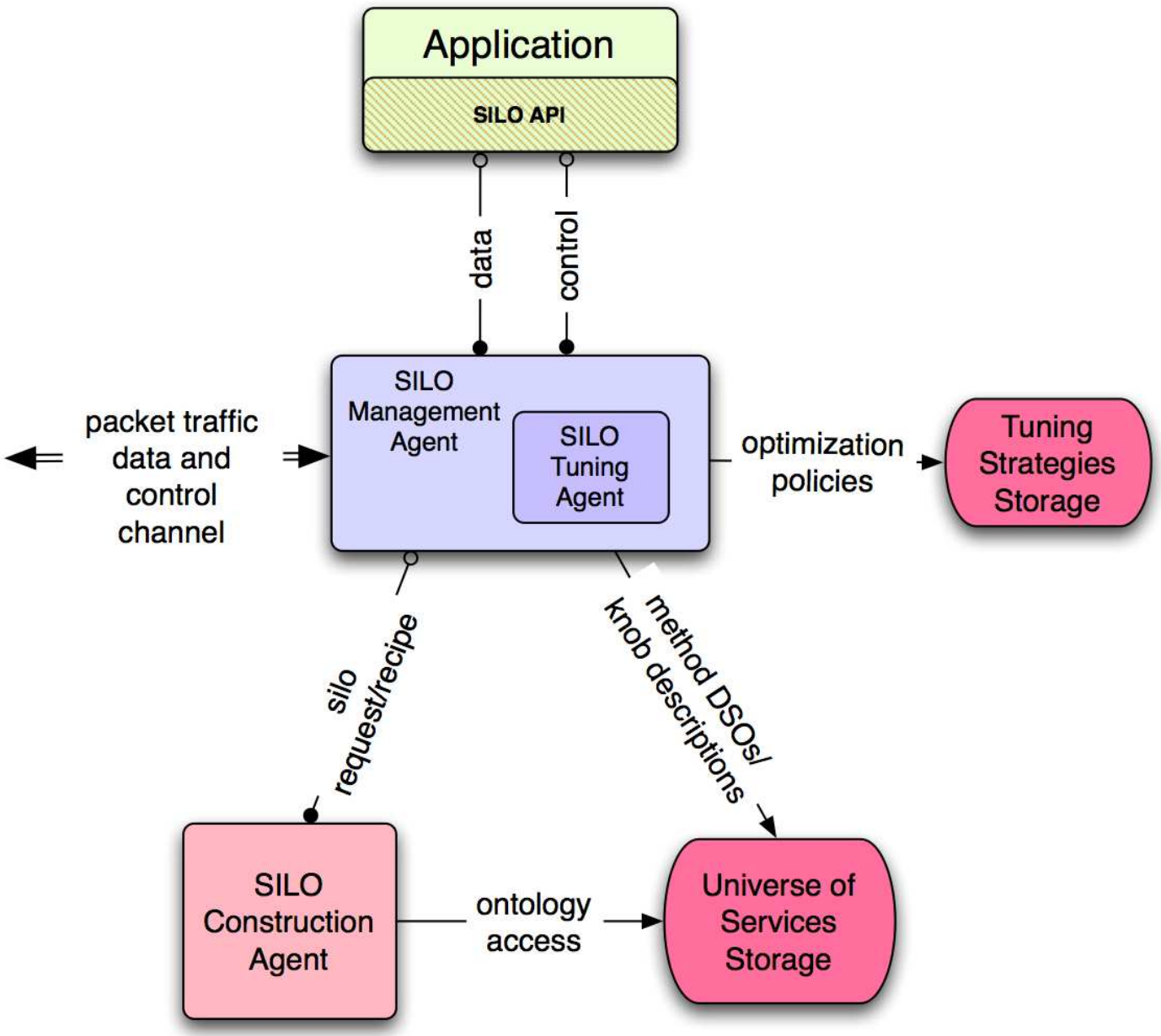
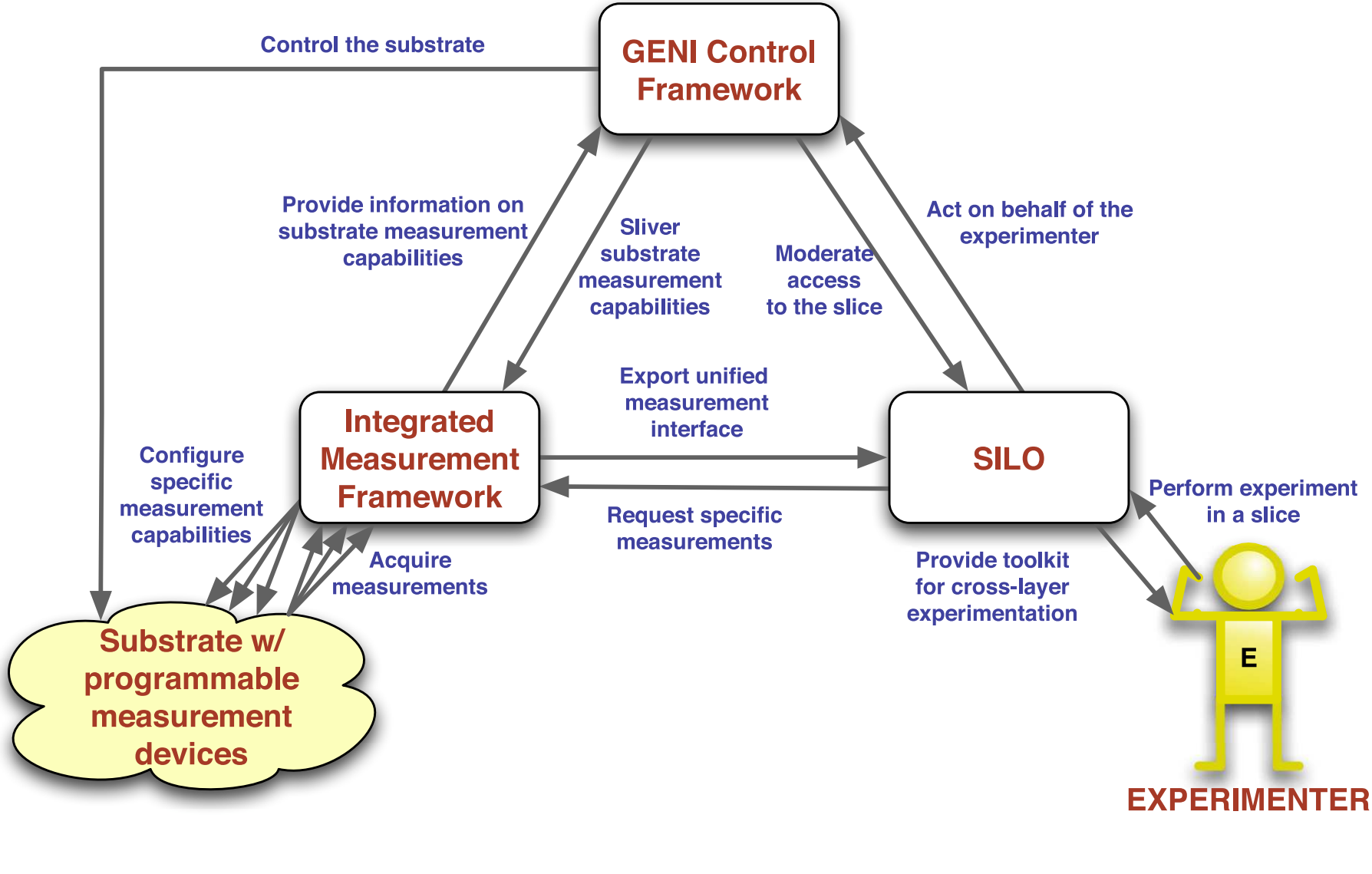
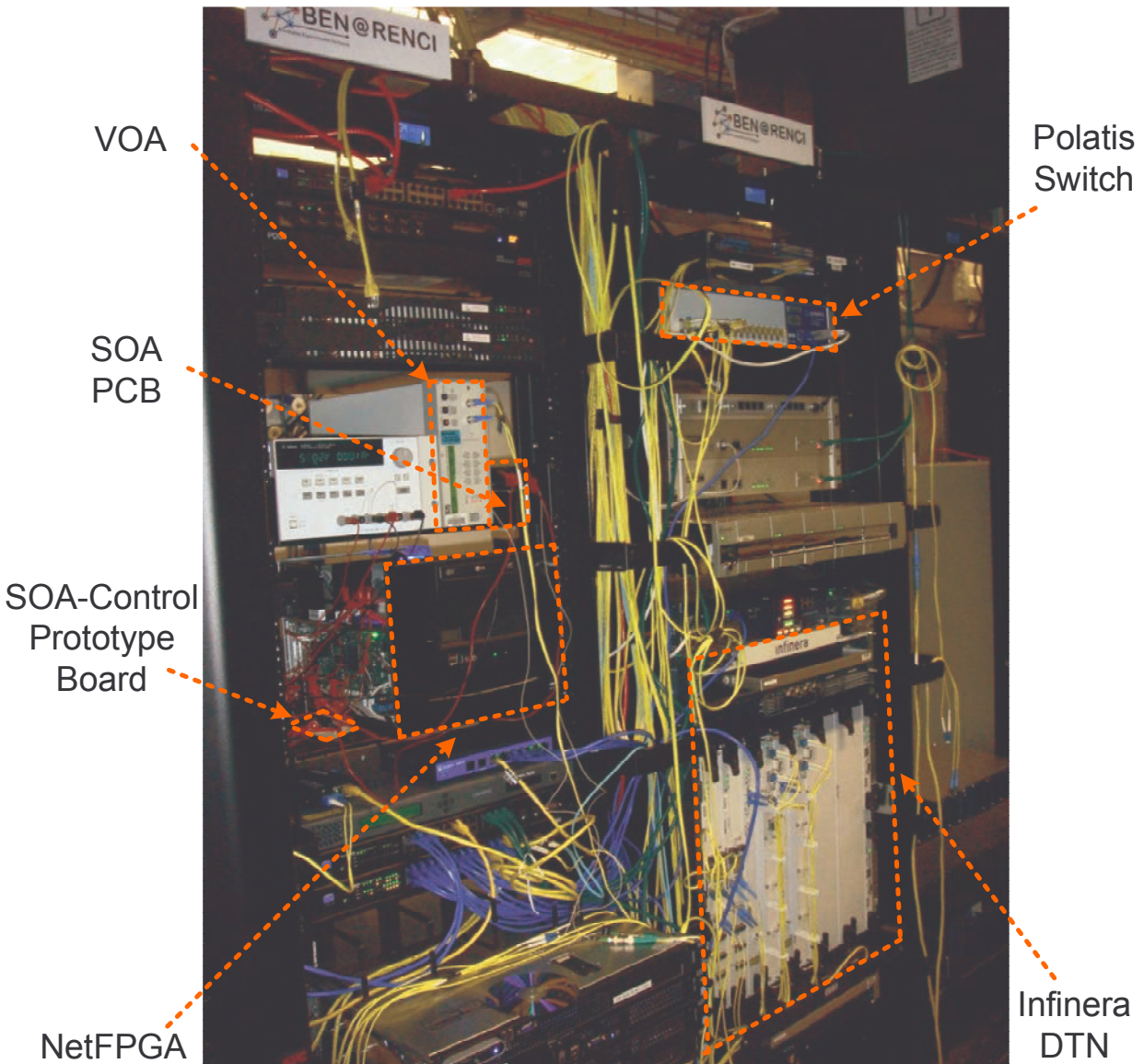
# Prototype Architecture



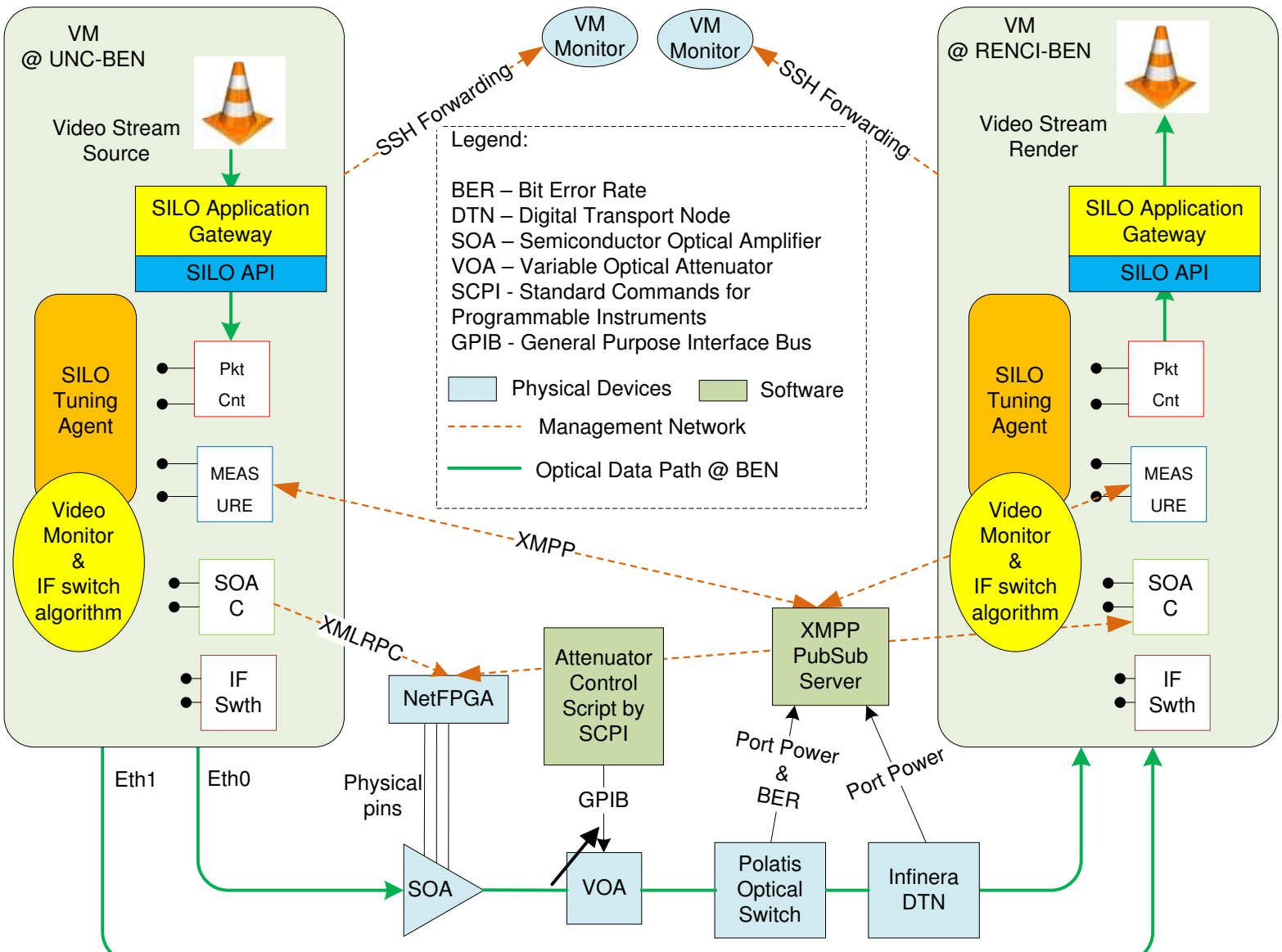
# SILO As a Research Tool



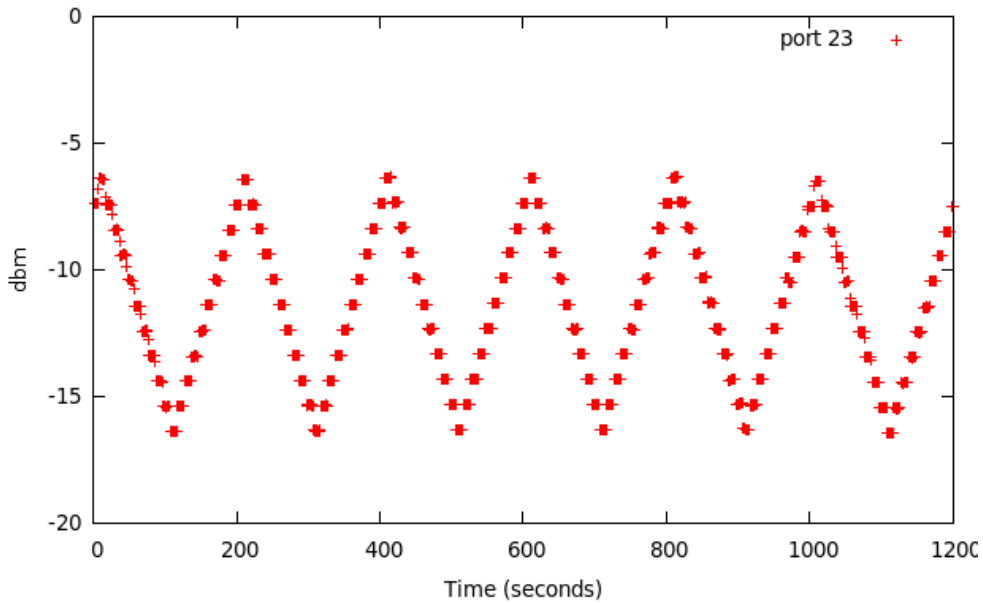
# IMF Physical Infrastructure



# IMF Cross-Service Demo



# IMF Demo – Results



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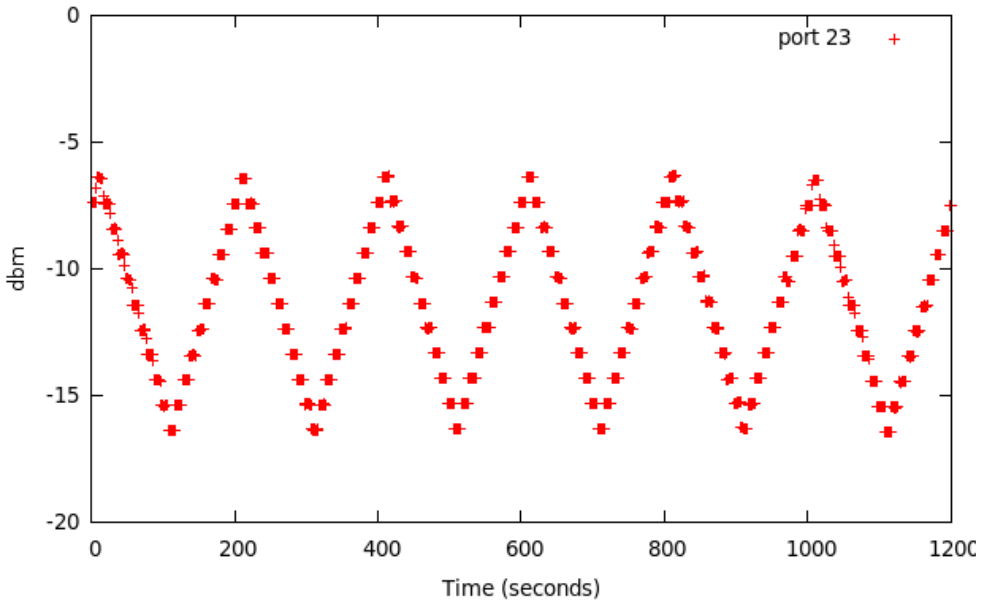


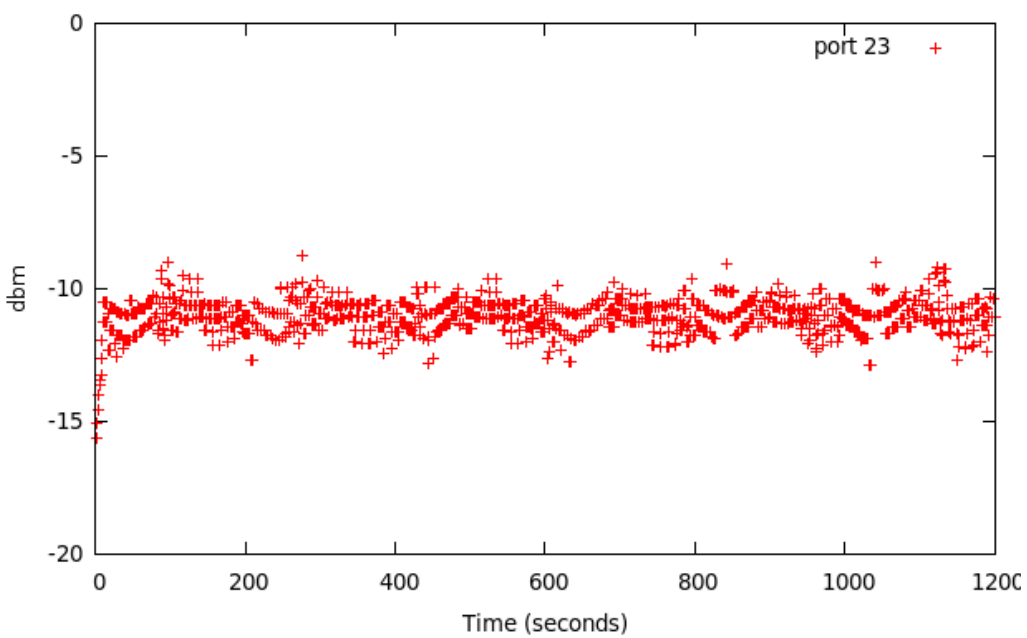

# Summary

- 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 $\longrightarrow$ breakable experimental net (BEN)

# Upcoming Book