Net SILOs: Generalizing the Layered Network Architecture

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http://net-silos.net/

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Outline

- Context: Layering and the Clean-Slate Debate
- Motivation: Software Defined Optics
- SILO Network Architecture: The Story So Far
- Summary and Future Directions

Context (1)

The Internet is broken!

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The Internet is broken! (has ossified / reached an impasse)

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Security needs an overhaul: it is difficult to

- identify users
- hold them accountable for their actions
- prevent them from causing harm

Context (1)

The Internet is broken!

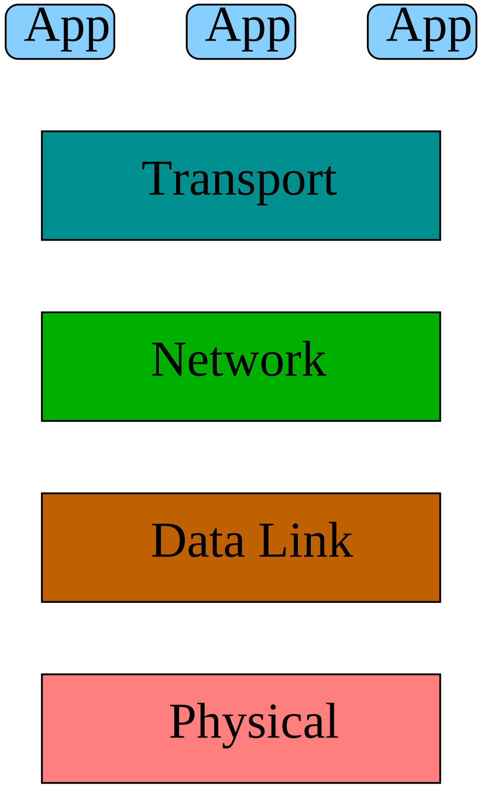
Middleboxes violate end-to-end principle:

- firewalls
- NAT
- proxies

Context (1)

The Internet is broken!

Fixed layer architecture is outdated



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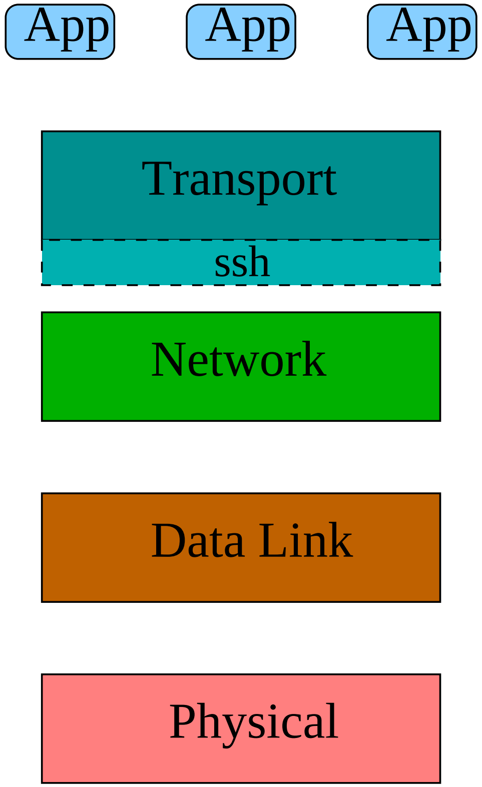

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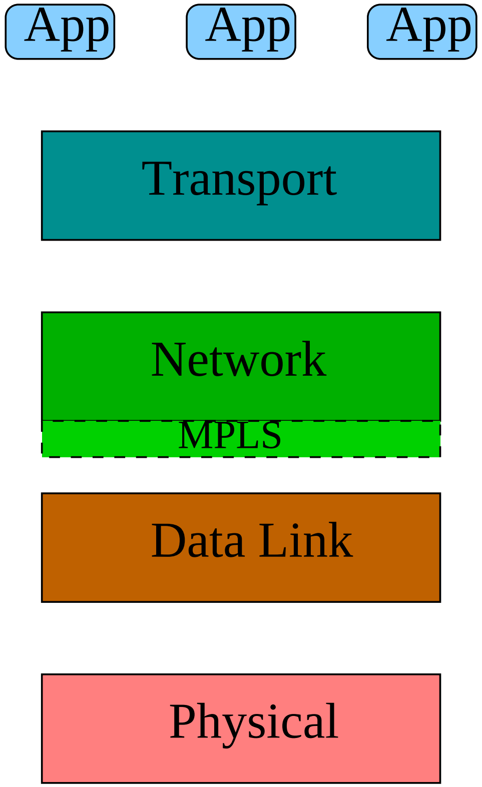
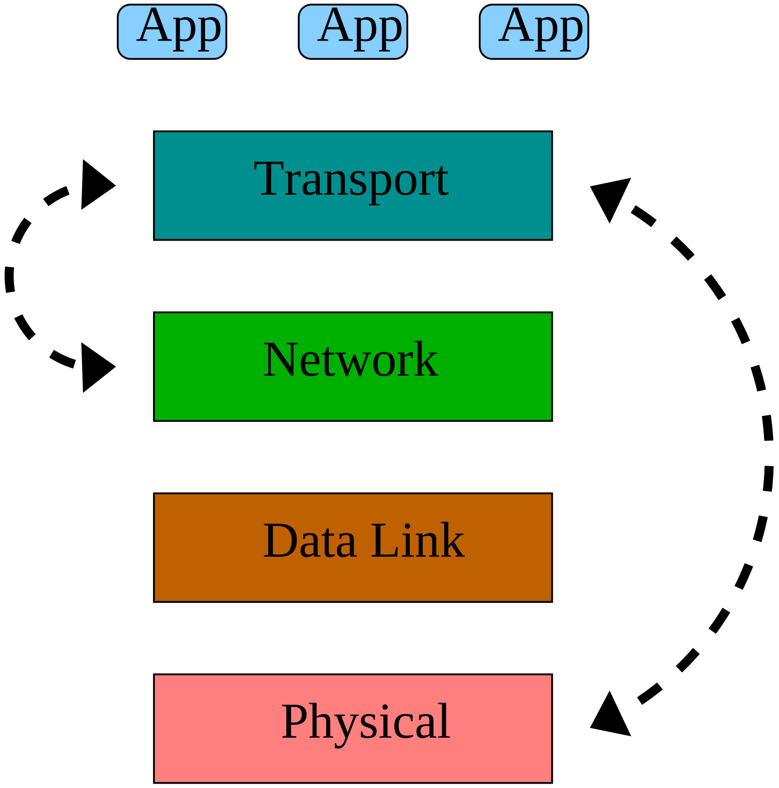


Context (1)

The Internet is broken!

Cross-layer interactions difficult: TCP over wireless



Context (1)

The Internet is broken!

Clear need for clean-state initiatives → NSF FIND, EU FIRE, $\cdots$

1. research in new network architectures
2. large-scale experimental facilities → GENI

Context (2)

The Internet is doing just fine, thank you!

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- Biological metaphor: mutation and natural selection
- Evolutionary designs: more robust, less expensive
- Mid-layer protocols must be conserved – not ossified
  → innovation at lower/upper layers of architecture

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  → innovation at lower/upper layers of architecture

→ Evolution beats revolution

Context (3)

Layering as optimization decomposition [CLCD 2007] [LSS 2006]

- Protocol layers integrated into mathematical framework
- Global optimization problem: network utility maximization
- Decomposition into subproblems $\longrightarrow$ layering
  - optimal modules (protocols) map to different layers
  - interfaces between layers coordinate the subproblems

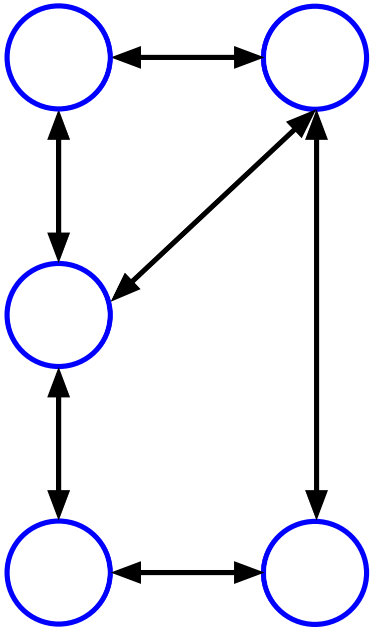
Context (3)

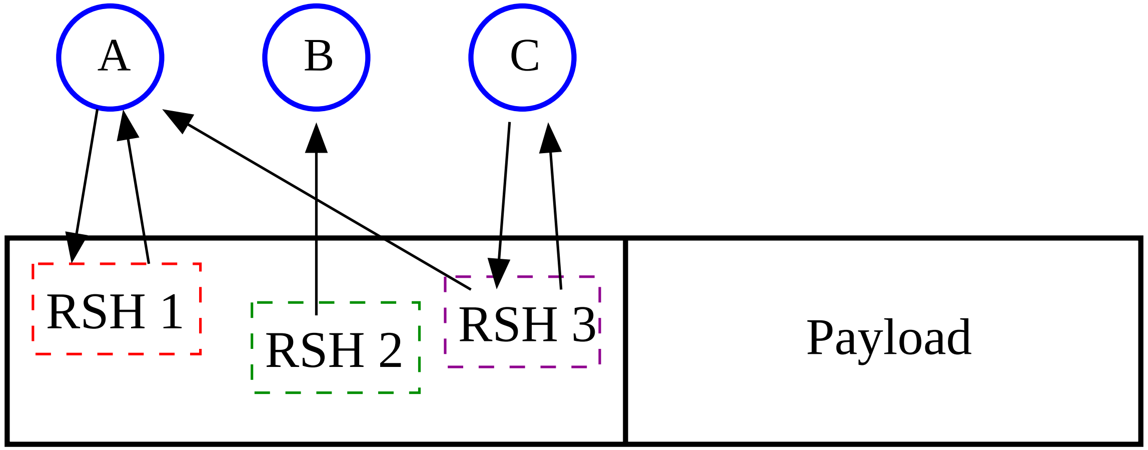
Layering as optimization decomposition [CLCD 2007] [LSS 2006]

- Clean-state optimization $\longrightarrow$ layered network architecture
  - optimal layering $\neq$ TCP/IP stack
  - various representations of optimization problem $\longrightarrow$ different layered architectures
  - (loose) coupling among layers $\longrightarrow$ cross-layer considerations

Role-Based Architecture (RBA) [BFH 2003]

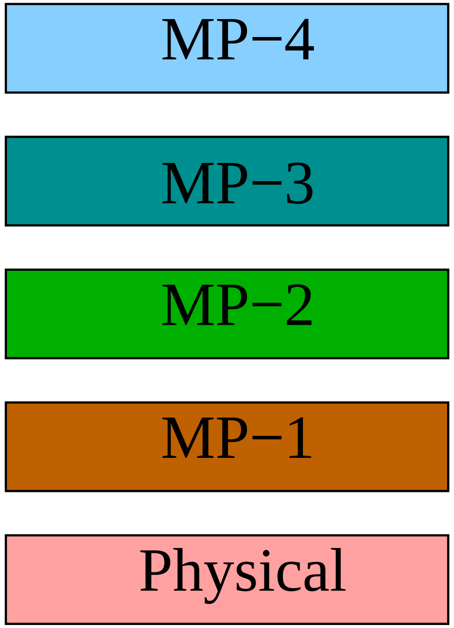
- New abstraction: organize protocols in heaps, not stacks
- Richer interactions among protocols → flexibility
- Require new system-level implementations





Recursive Network Architecture (RNA) [TP 2008]

- Meta-protocol: generic protocol layer with basic services
- Each layer in stack → appropriately configured instantiation
- Allows reuse, cleaner cross-layer interactions, dynamic composition



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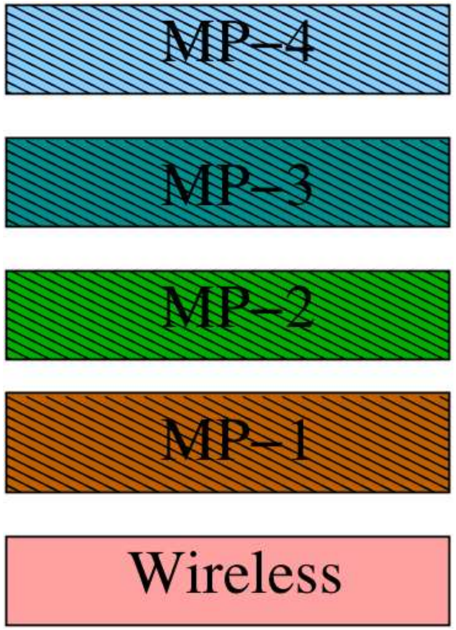

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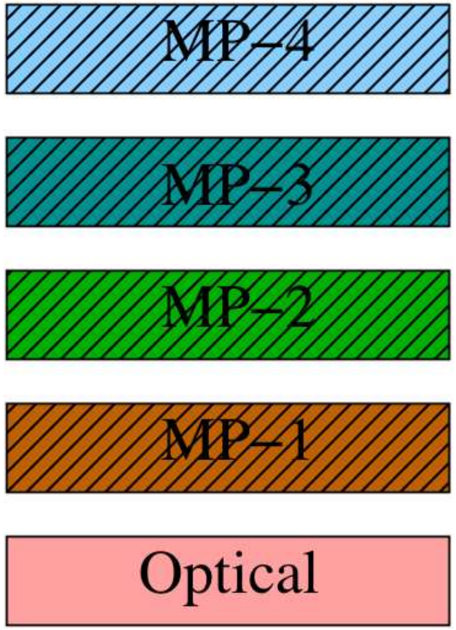

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- New architecture must be designed for adaptability/evolvability
- New architecture must preserve/generalize layering
- SILO objective:

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

Software Defined Optics

- Optical substrate can no longer be viewed as black box

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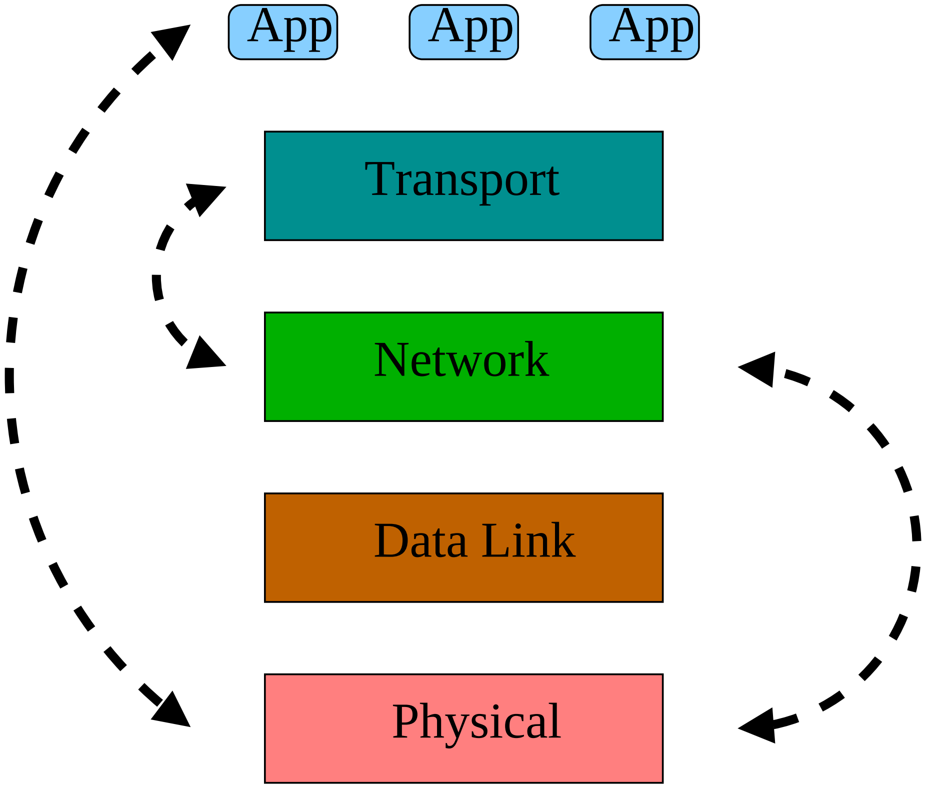
- Collection of intelligent and programmable resources:

Software Defined Optics

- Optical substrate can no longer be viewed as black box
- Collection of intelligent and programmable resources:
  - optical monitoring, sensing mechanisms
  - amplifiers, impairment compensation devices
  - tunable optical splitters
  - configurable add-drop
  - programmable mux-demux (e.g., adjust band size)
  - adjustable slot size
  - . . .

Cross-Layer Interactions

- Impairment-aware RWA and network design
- Placement of optical sub-systems (converters, amplifiers, regenerators)
- Traffic grooming
- Inter-layer QoS and traffic engineering
- Optical layer multicast
- Multi-layer failure localization and recovery
- . . .



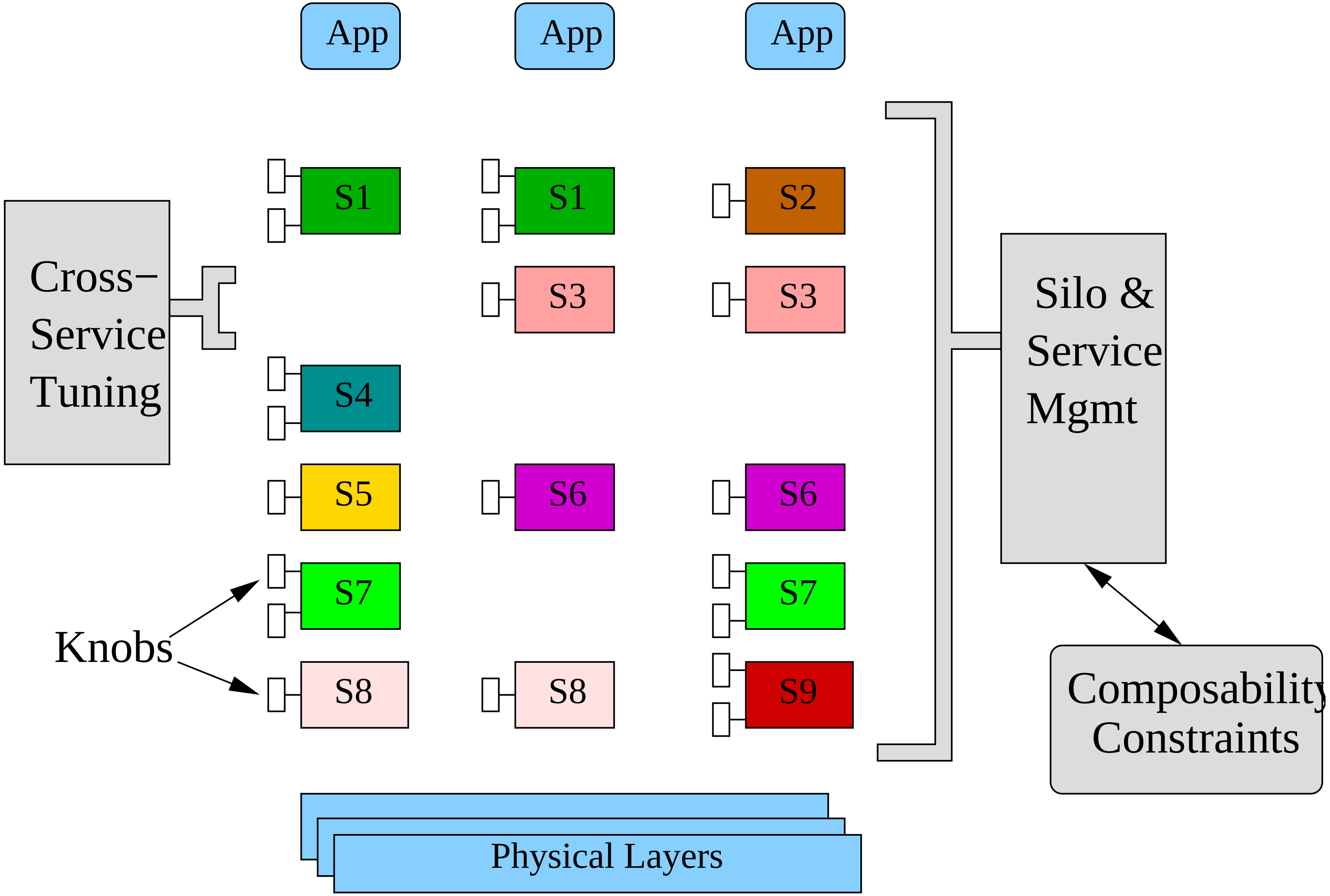
SILO Architecture Highlights

- Services: building blocks of fine-grain functionality → reusability
- Generalizes traditional layer stack
- Enables inter-layer interactions:
  - knobs: explicit control interfaces
- Design for change:
  - facilitates introduction of new services

Generalization of Layering

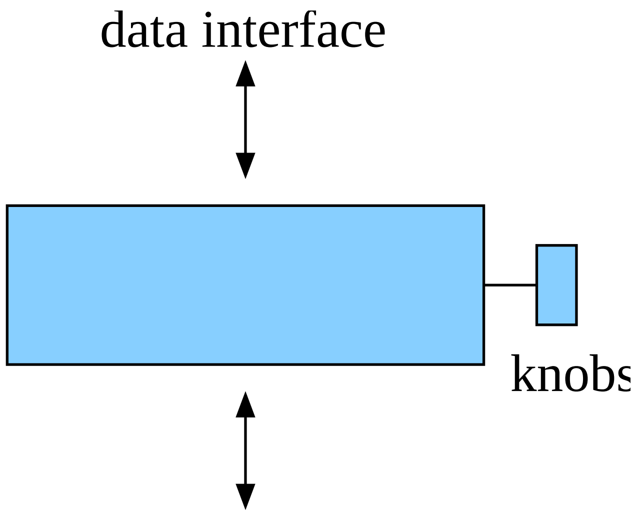
- Silo: vertical composition of services
  → preserves layering principle
- Per-flow instantiation of silos
  → introduces flexibility and customization
- Decoupling of layers and services
  → services introduced at point in stack where necessary

Silos: Generalized Protocol Stacks



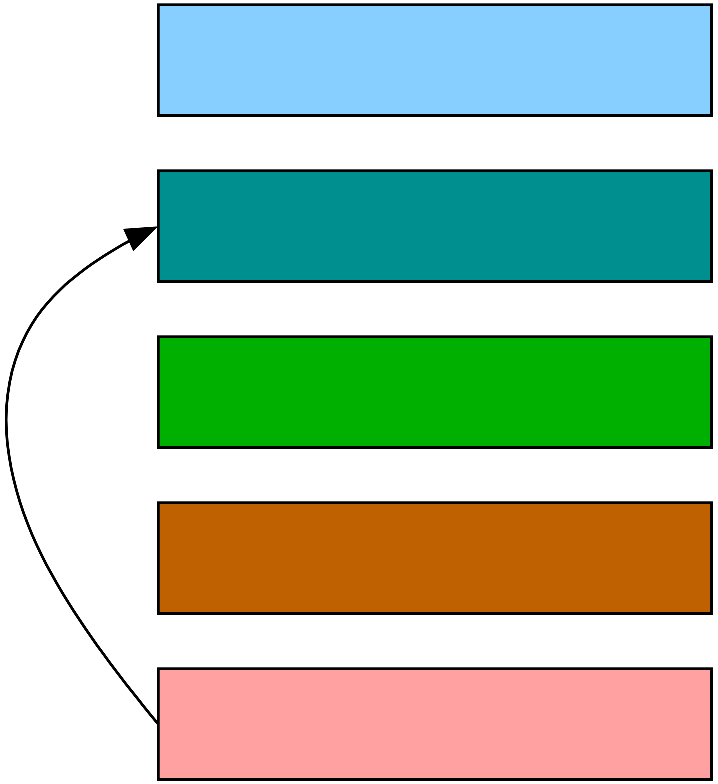
Inter-Layer Interactions (1)

- 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



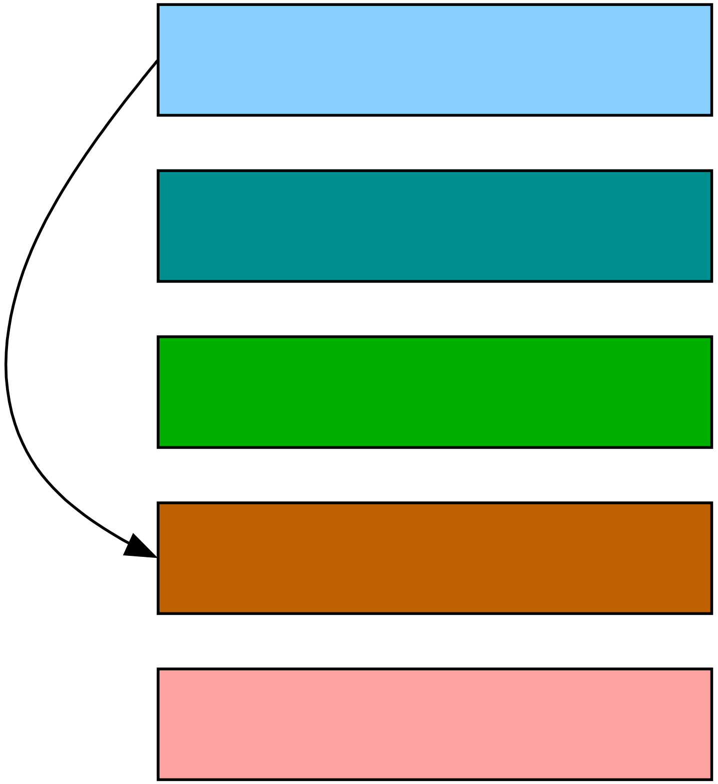
Inter-Layer Interactions (2)

Upward information passing



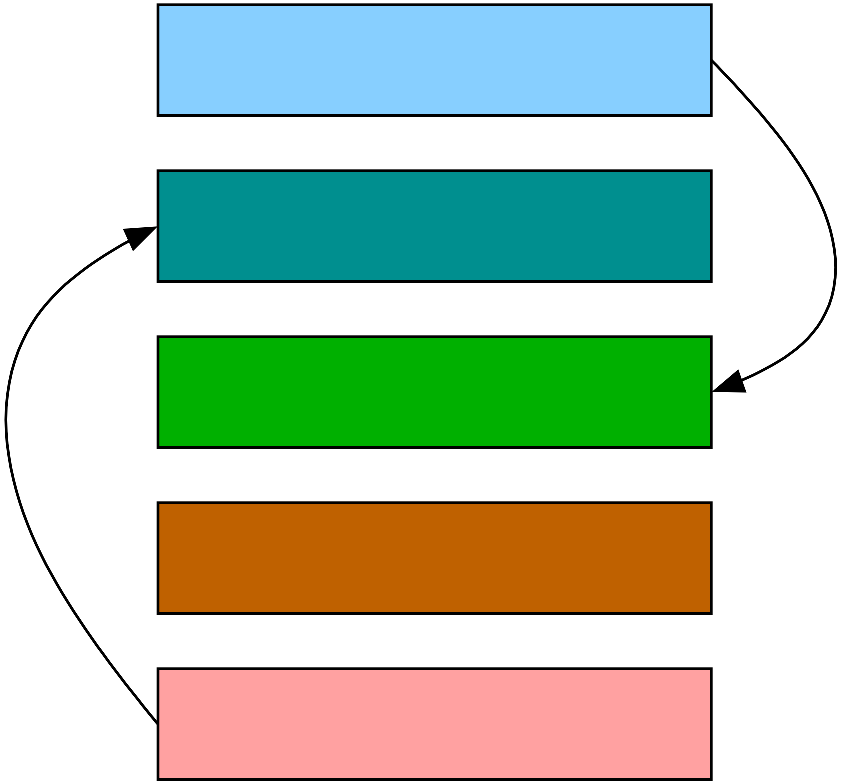
Inter-Layer Interactions (2)

Downward information passing



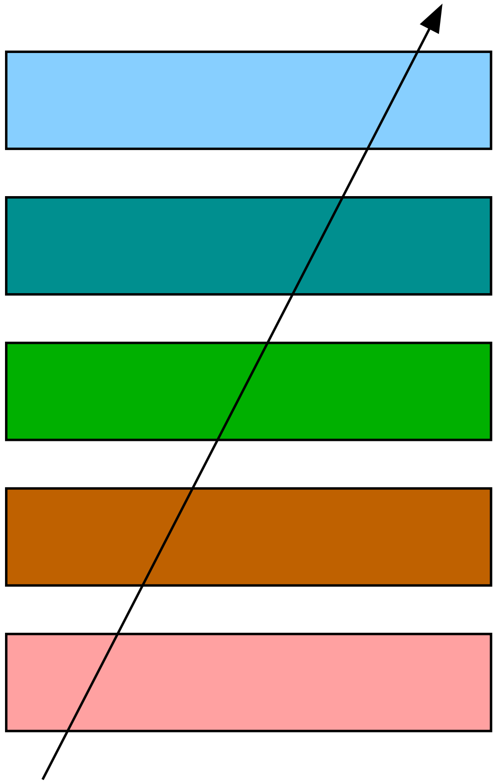
Inter-Layer Interactions (2)

Up-and-down information passing



Inter-Layer Interactions (2)

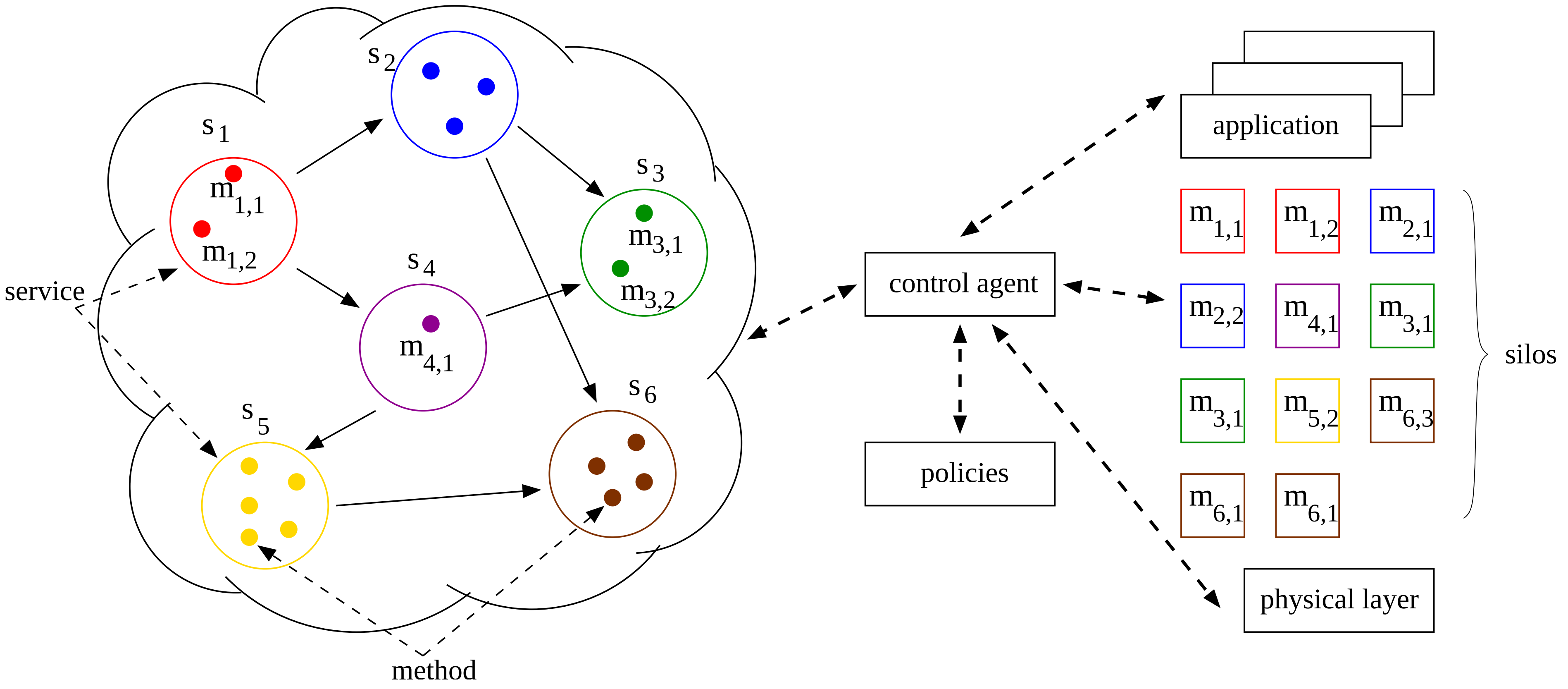
Silo-wide optimization/calibration



Design for Change

- Architecture does not dictate services to be implemented
- Provide mechanisms for:
  - 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

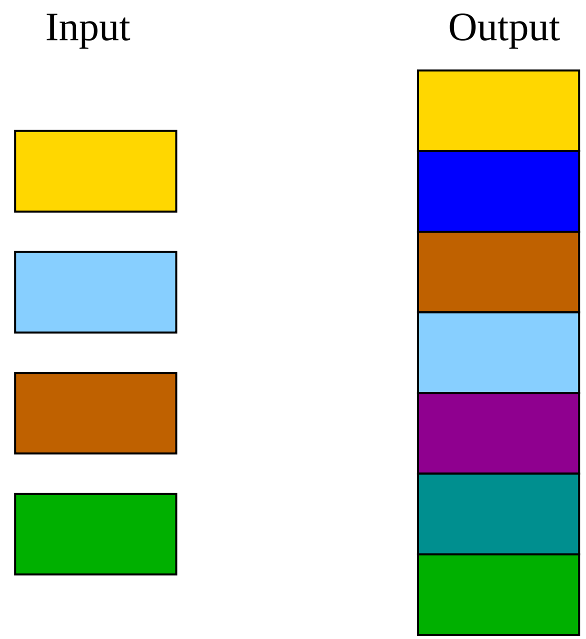


Service Composition

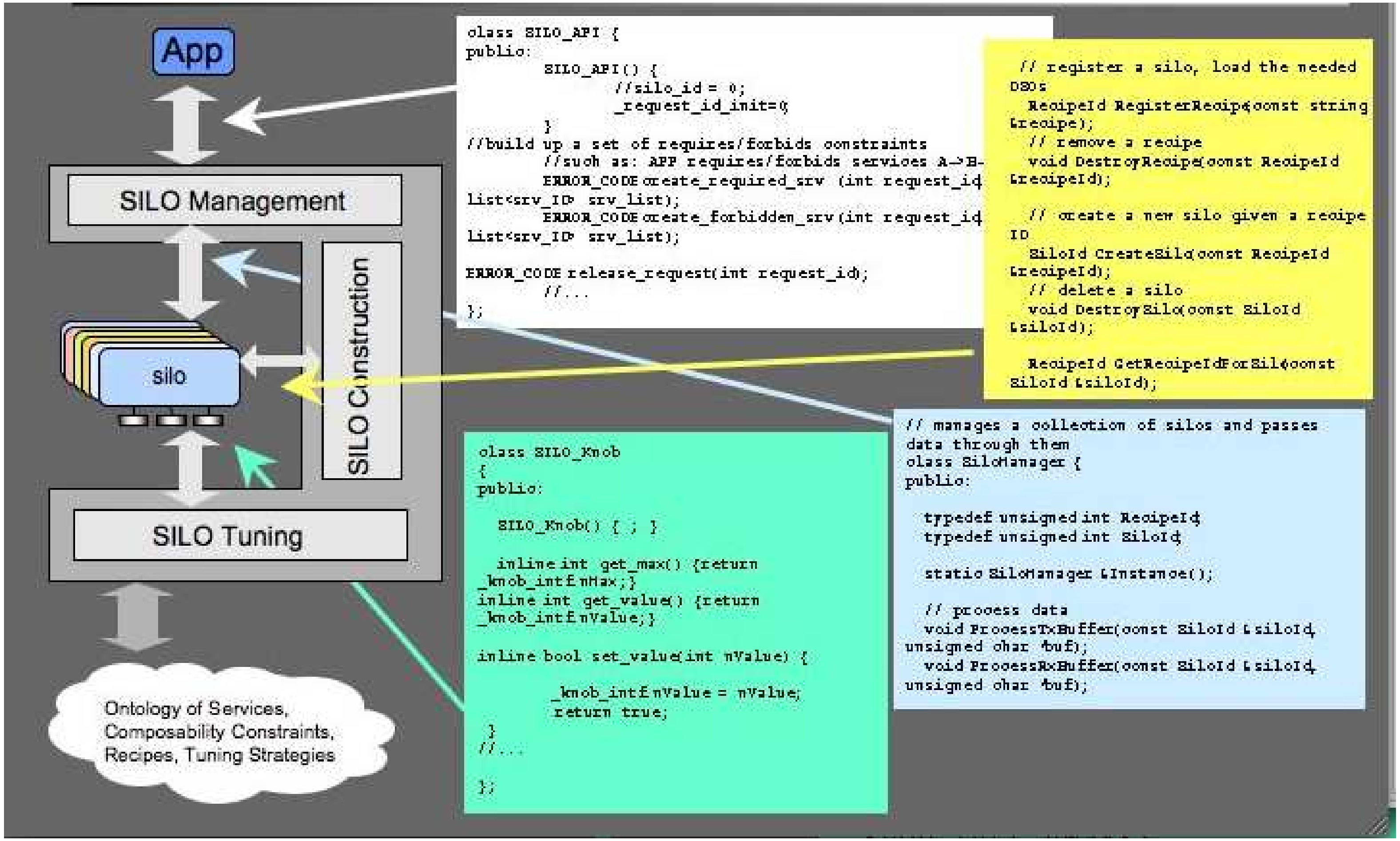
- Constraints on composing services A and B:
  - A requires B
  - A forbids B
  - A must be above (below) B
  - A must be immediately above (below) B
  - Negations, AND, OR
- Minimal set:
  - Requires, Above, ImmAbove, NotImmAbove
- All pairwise condition sets realizable
  - Forbids = (A above B) AND (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



SILO Software Prototype



```
class SILO_API {
public:
        SILO_API() {
                //silo_id = 0;
                _request_id_init=0;
        }
//build up a set of requires/forbids constraints
        //such as: APP requires/forbids services A->B-
        ERROR_CODE create_required_srv (int request_id,
list<srv_ID> srv_list);
        ERROR_CODE create_forbidden_srv(int request_id,
list<srv_ID> srv_list);

ERROR_CODE release_request(int request_id);
        //...
};
```

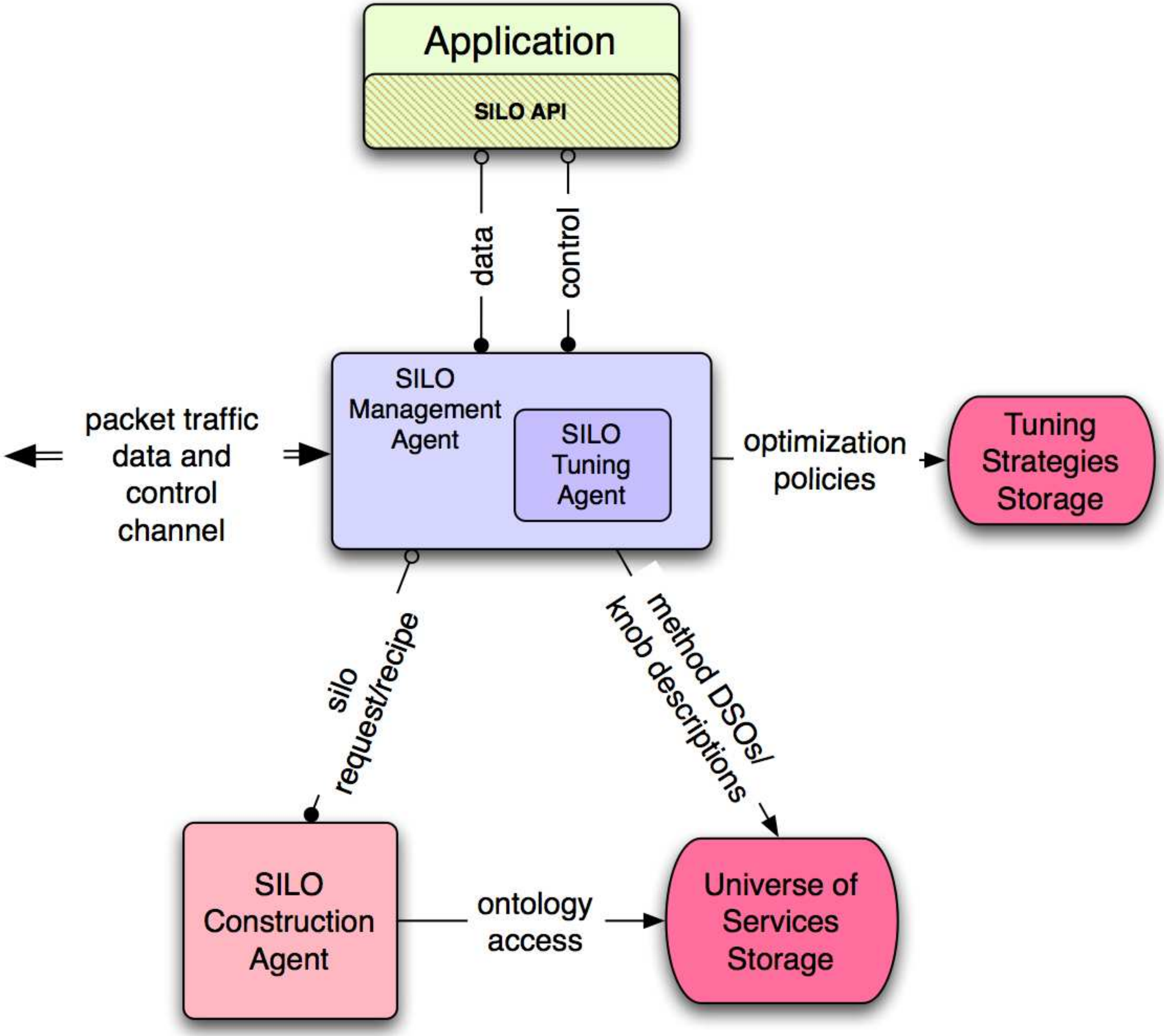
```
 // register a silo, load the needed
DSOs
  RecipeId RegisterRecipe(const string
&recipe);
  // remove a recipe
  void DestroyRecipe(const RecipeId
&recipeId);

  // create a new silo given a recipe
ID
  SiloId CreateSilo(const RecipeId
&recipeId);
  // delete a silo
  void DestroySilo(const SiloId
&siloId);

  RecipeId GetRecipeIdForSilo(const
SiloId &siloId);
```

```
class SILO_Knob
{
public:

  SILO_Knob() { ; }

  inline int get_max() {return
_knob_intf.nMax;}
inline int get_value() {return
_knob_intf.nValue;}

inline bool set_value(int nValue) {

        _knob_intf.nValue = nValue;
        return true;
 }
//...

};
```

```
// manages a collection of silos and passes
data through them
class SiloManager {
public:

  typedef unsigned int RecipeId;
  typedef unsigned int SiloId;

  static SiloManager &Instance();

  // process data
  void ProcessTxBuffer(const SiloId &siloId,
unsigned char *buf);
  void ProcessRxBuffer(const SiloId &siloId,
unsigned char *buf);
```

http://net-silos.net/

Prototype Architecture



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
  - software defined optics
  - virtualization and slicing
- Extend the prototype
  - portfolio of reusable services
  - deployment in optical testbed ⟶ breakable experimental network (BEN)
- Explore synergies with other (FIND) projects