

Perspectives on Future Internet Design

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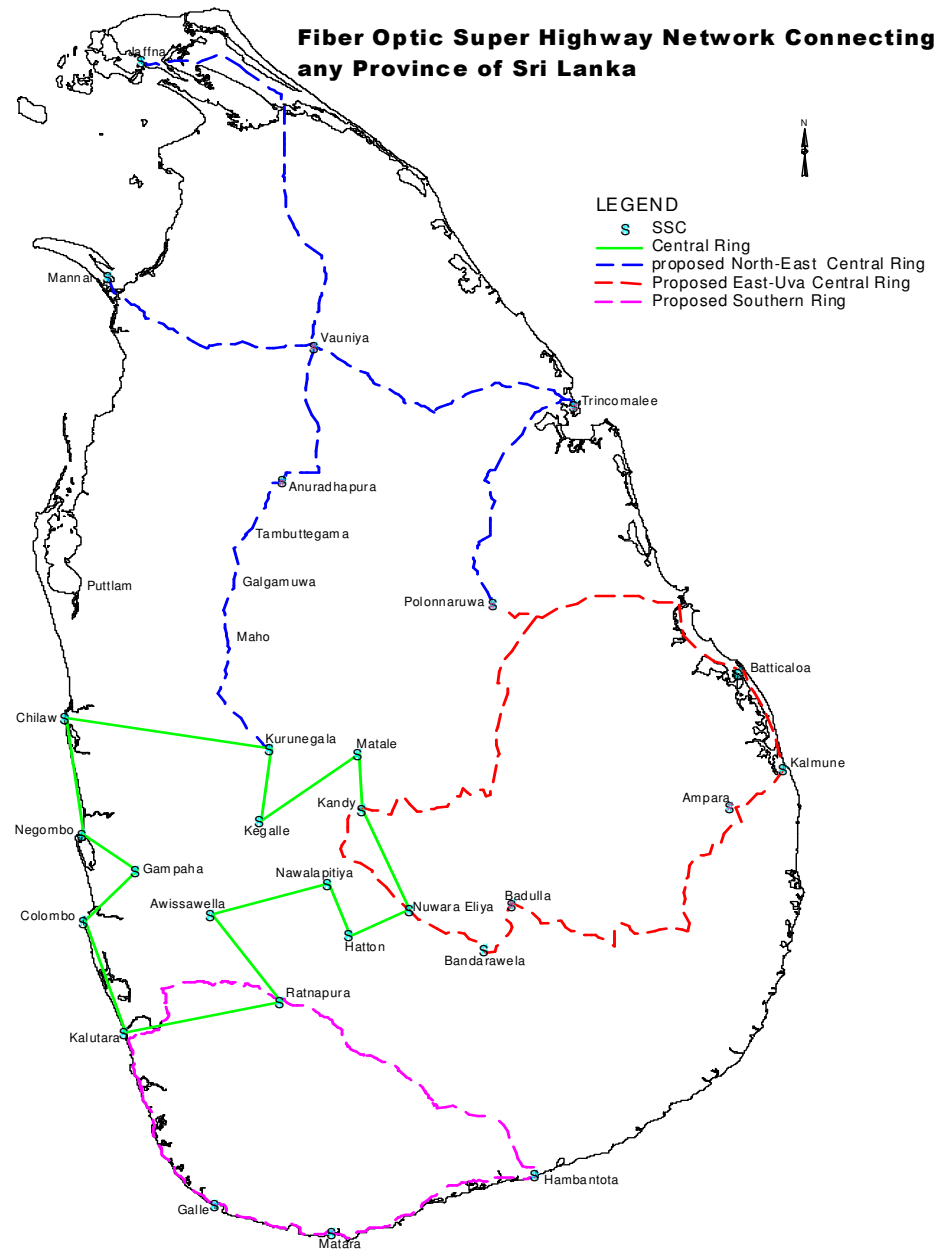
North Carolina State University

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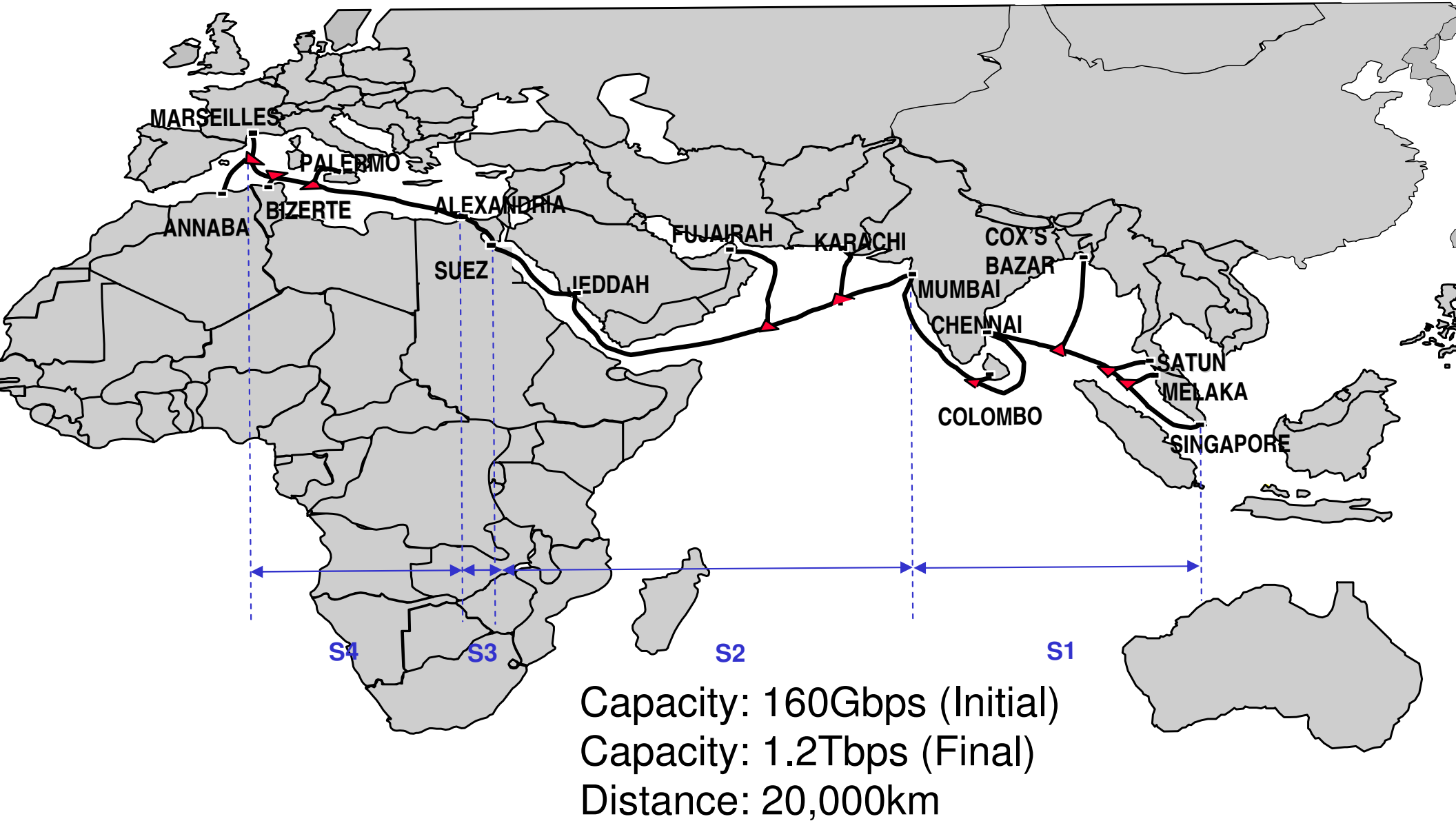
Outline

- Research on Future Internet Architectures
- Our Experience:
 - SILO and GENI IMF: Design for Change
 - ChoiceNet: Design for Choice

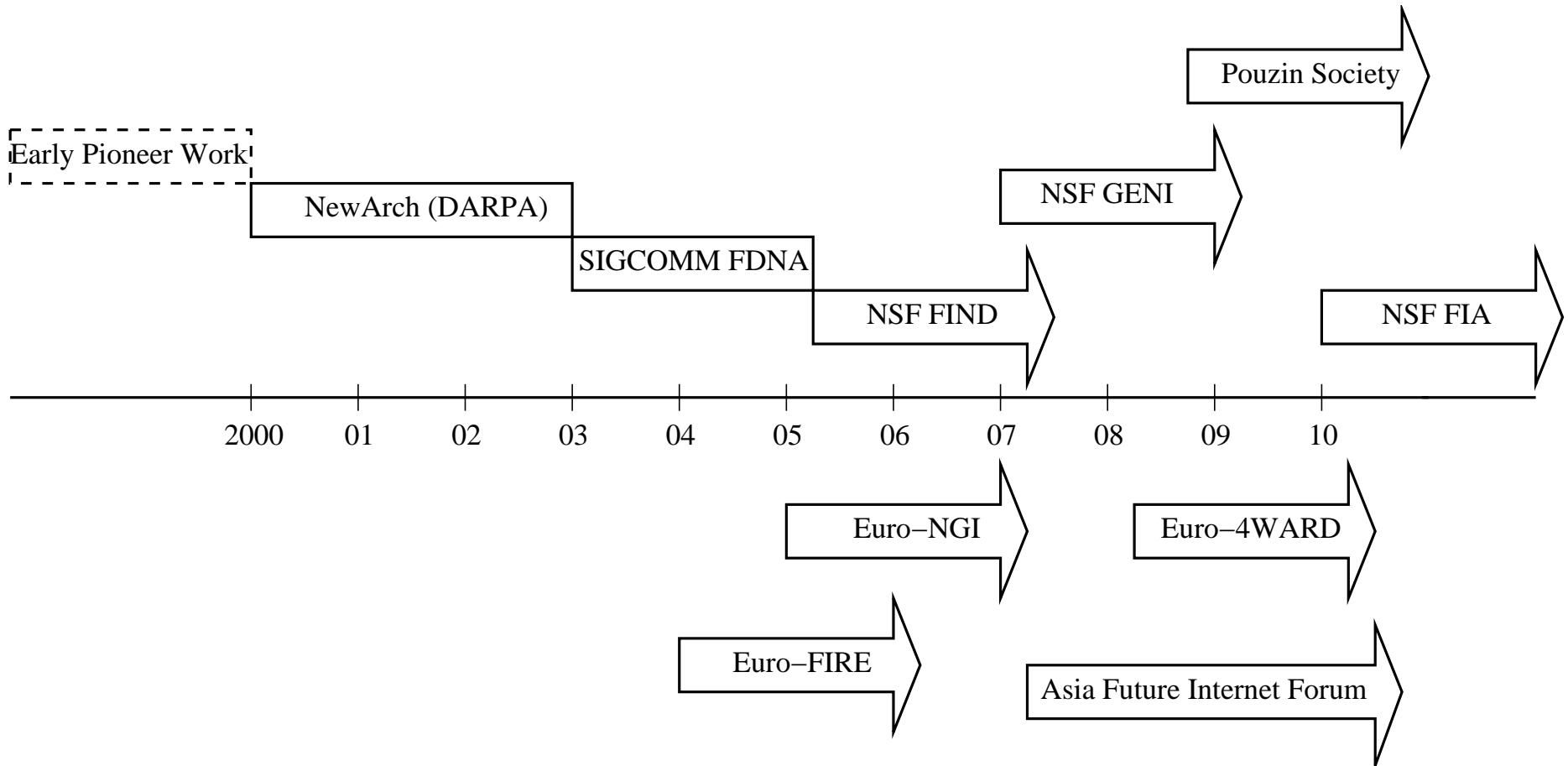
Sri Lanka Fiber Connectivity



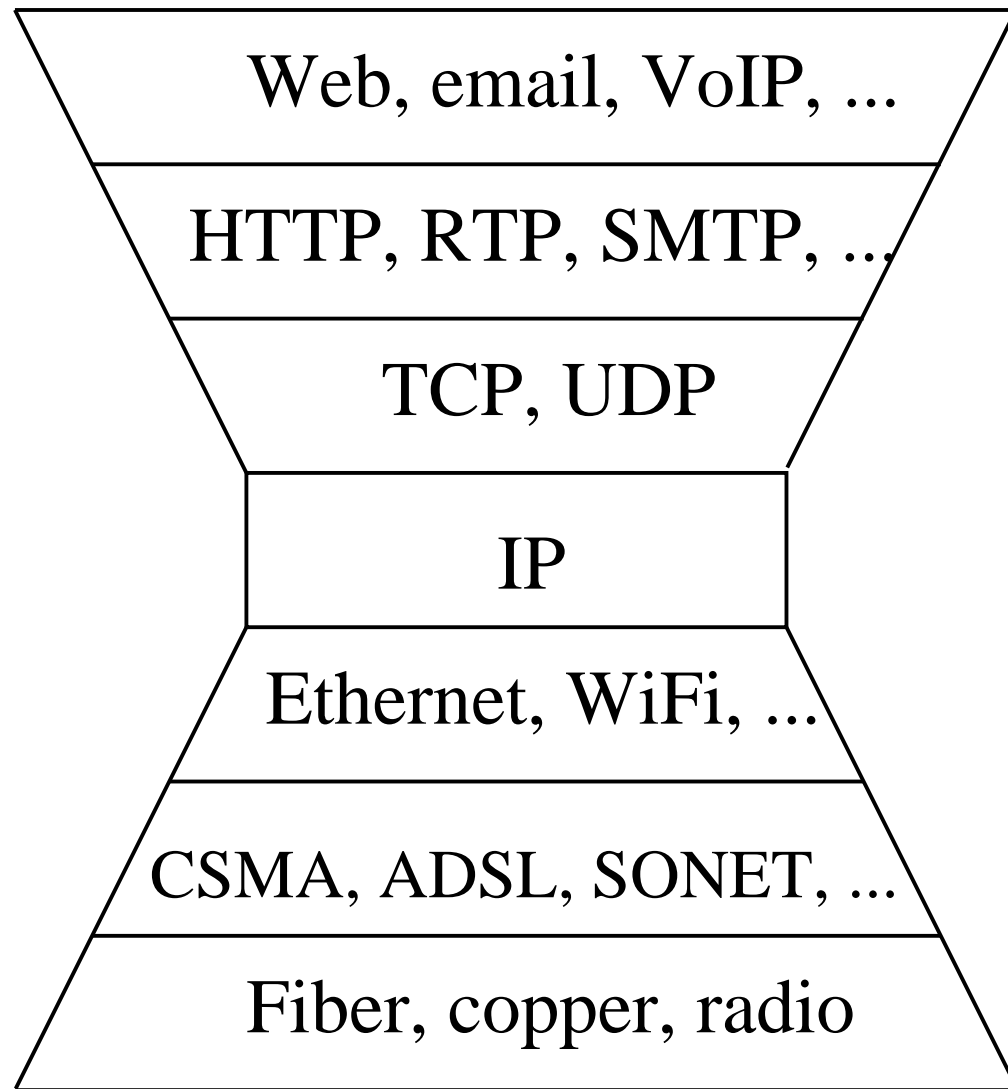
SEA-ME-WE-4



Historical Perspective



Current Internet Architecture



Shift in Requirements

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- **Focus:** Machine-to-machine → Human-to-human

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- 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

Clean Slate Design

- Design a system “from scratch”:
 - without being restrained by existing system
 - using accumulated knowledge and experience
 - having a fresh, unbiased look at the problem space
- Several challenges:
 - holistic approach considering all aspects
 - overall redesign of the architecture
 - experimentation “at scale”
 - gain insight, mitigate risk
 - accommodate future changes

Three-Step Approach

1. Innovations in **various specific aspects** of the Internet

- US: NSF Future Internet Design (FIND)
≈ 50 projects: SILO, PoMo, NetServices, . . .
- EU: Network of the Future
≈ 90 projects: Trilogy, Eiffel, Sensei, . . .
- Japan: New Generation Network (NWGN, shorter term)
- China: New Generation Trustworthy Networks, New Generation Network Architectures

Three-Step Approach (cont'd)

2. Collaborative projects: integrate innovations into overall architecture

- US: NSF Future Internet Architecture (FIA)
NDN, MobilityFirst, NEBULA, XIA
- EU: Future Internet Assembly (FIA)
4WARD
- Japan: NWGN (longer term)
AKARI
- China: Future Internet Architectures

Three-Step Approach (cont'd)

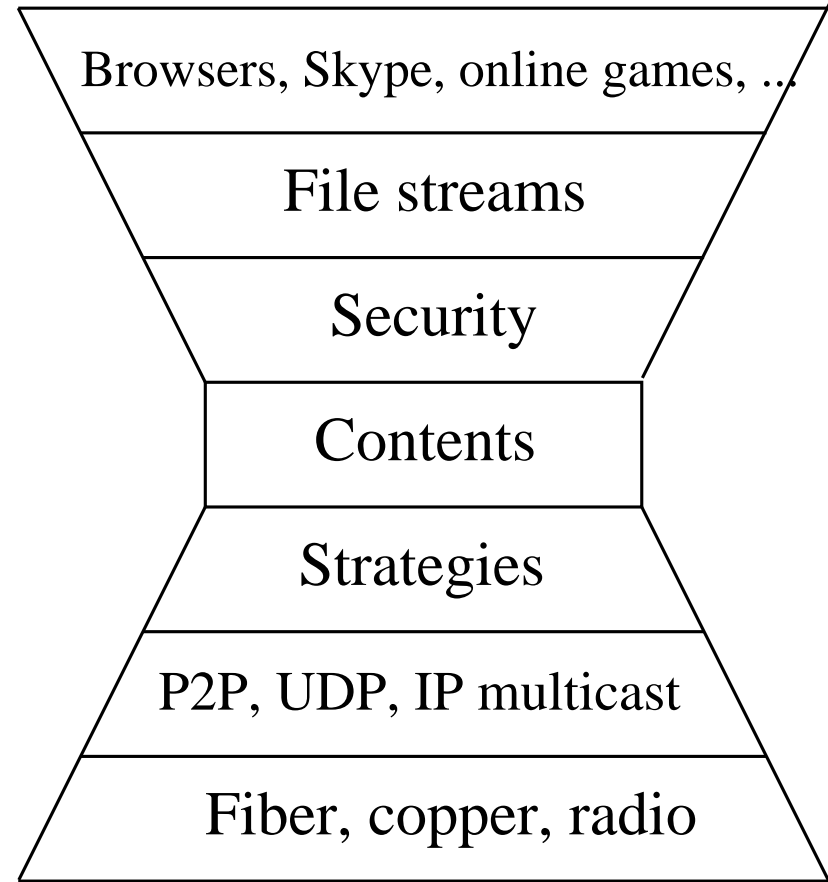
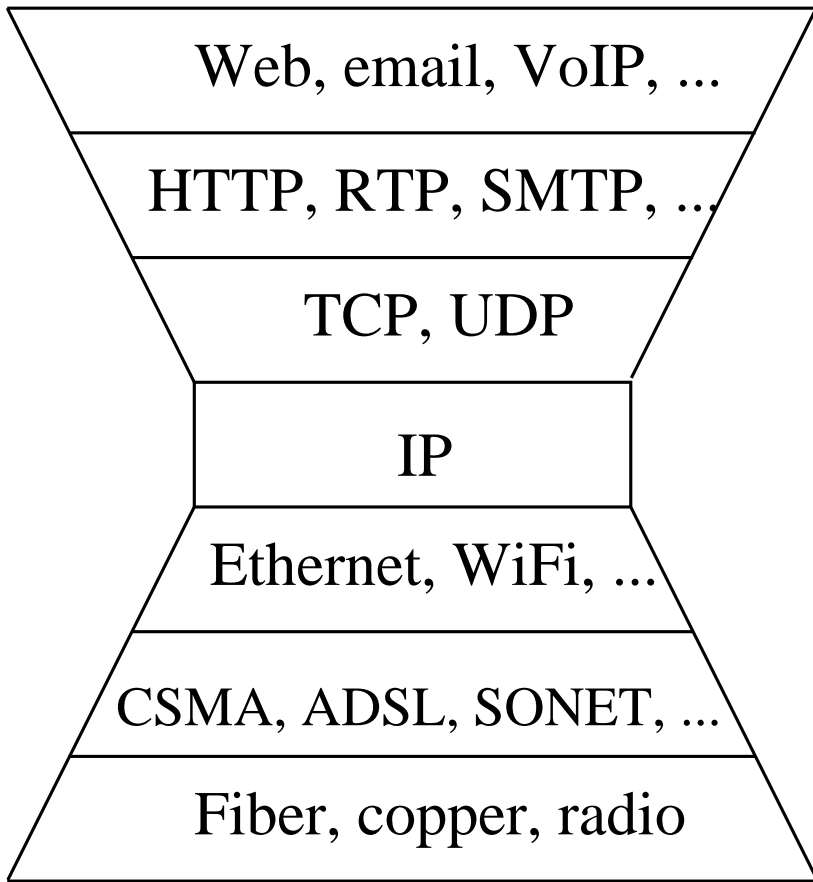
3. **Testbeds** for real-scale experimentation

- US: Global Environment for Network Innovations (GENI)
- EU: Future Internet Research and Experimentation (FIRE)
- Japan: JGN2+, JGN-X
- China: China Next Generation Internet (CNGI)

US FIA Projects

1. **Named Data Networking (NDN)** – UCLA (lead)
 - content-centric, focus on “what” not “where”
 - secure data, not transmission channel or data path
2. **MobilityFirst** – Rutgers (lead)
 - address cellular convergence (4-5B devices), connect vehicles
 - pervasive system to interface humans with physical world
3. **NEBULA** – UPenn (lead)
 - reliable, high-speed core interconnecting data centers
 - mobile “roaming” users connect to nearest data center
4. **eXpressive Internet Architecture (XIA)** – Carnegie Mellon (lead)
 - rich set of communication entities as network principals
 - intrinsic security using self-certifying identifiers

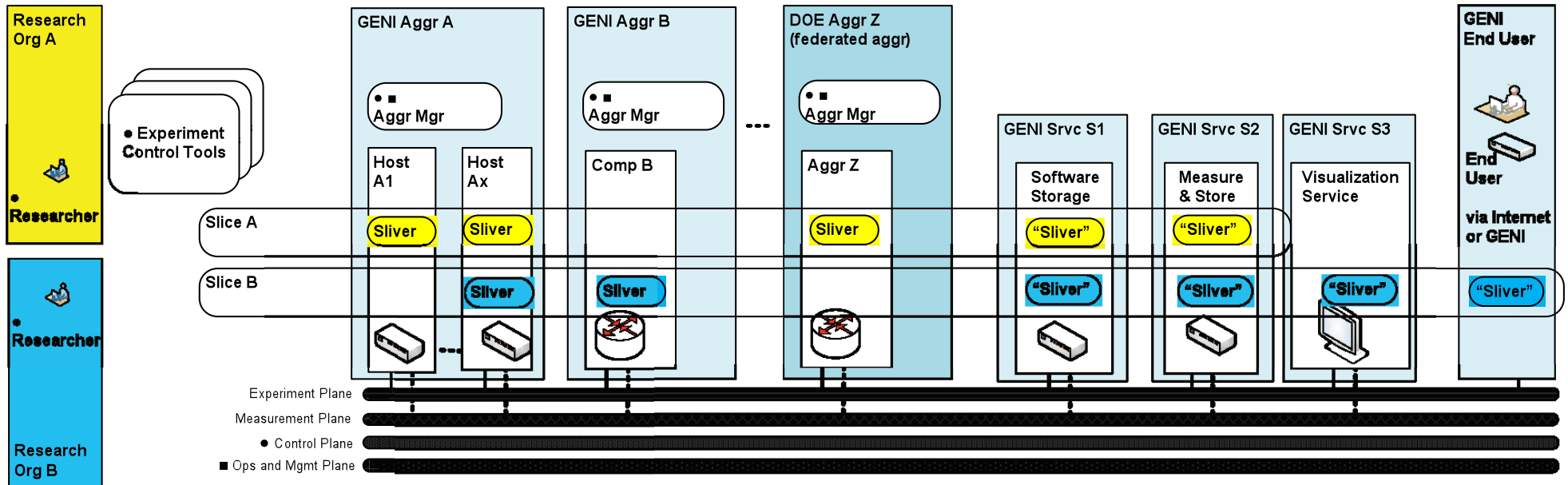
Narrow Waist of NDN



GENI: Core Concepts

- **Programmability:**
 - download SW into GENI nodes to control their behavior
- **Virtualization/Resource Sharing**
 - nodes implement virtual machines → shared infrastructure
 - experiments run within own, isolated slice of GENI resources
- **Federation**
 - different parts of GENI suite owned/operated by different entities
- **Slice-Based Experimentation**
 - connected set of reserved resources in diverse locations
 - remotely discover, reserve, program, operate, manage, teardown

GENI Slices



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fundamental elements/principles ↔ design decisions

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- 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

Meta-Design Framework

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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

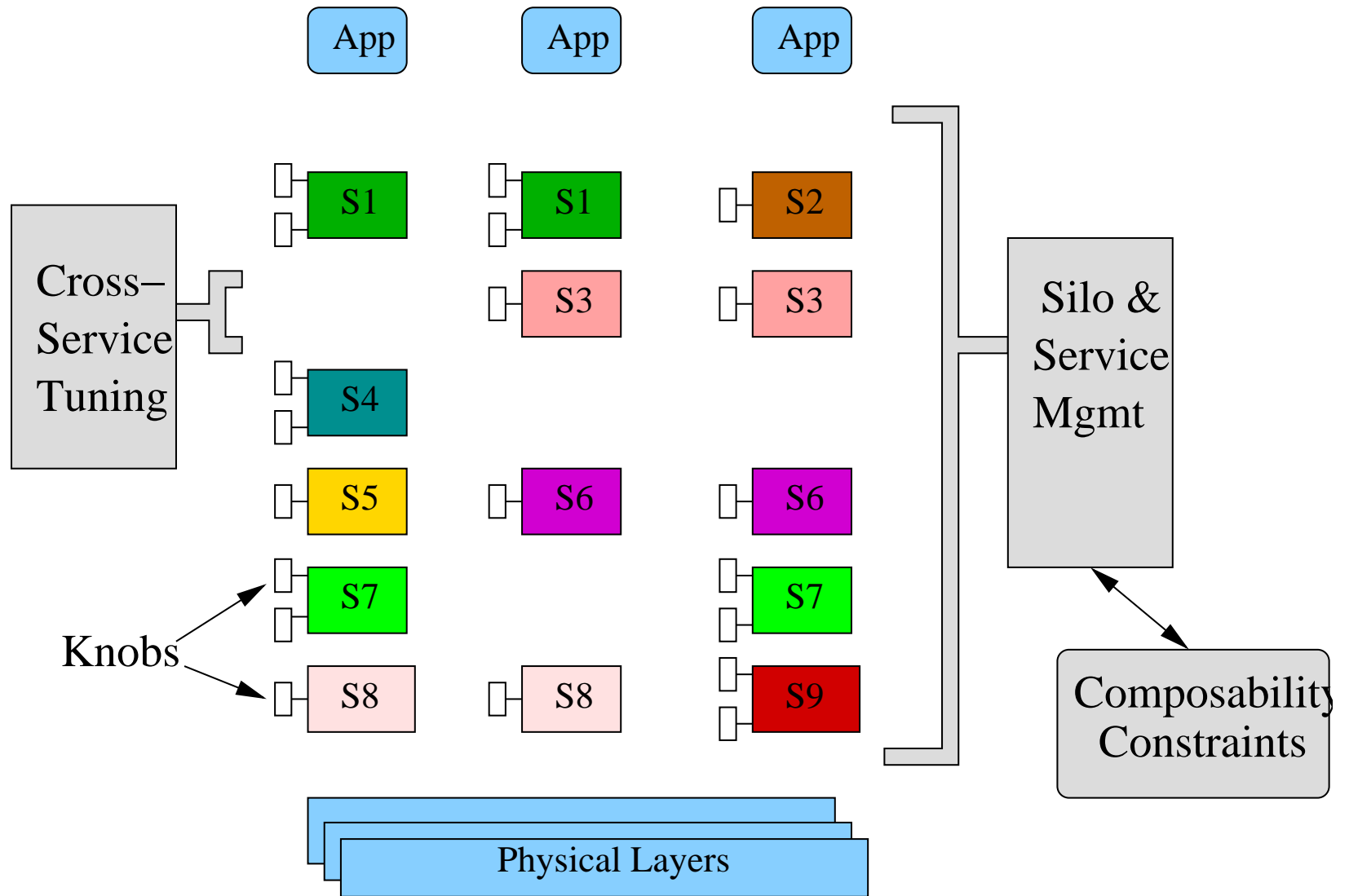
SILO Architecture Highlights

- **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

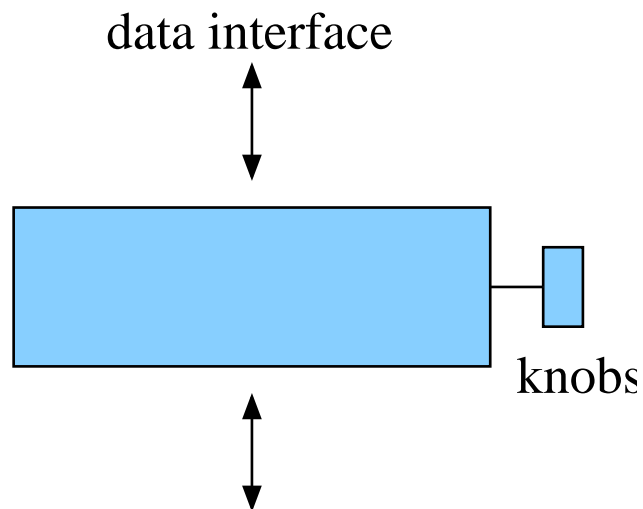
- **Silo:** vertical composition of services
→ preserves layering principle
- **Per-flow** instantiation of silos
→ introduces flexibility and customization
- **Decoupling** of layers and services
→ services introduced at point in stack where necessary

Silos: Generalized Protocol Stacks



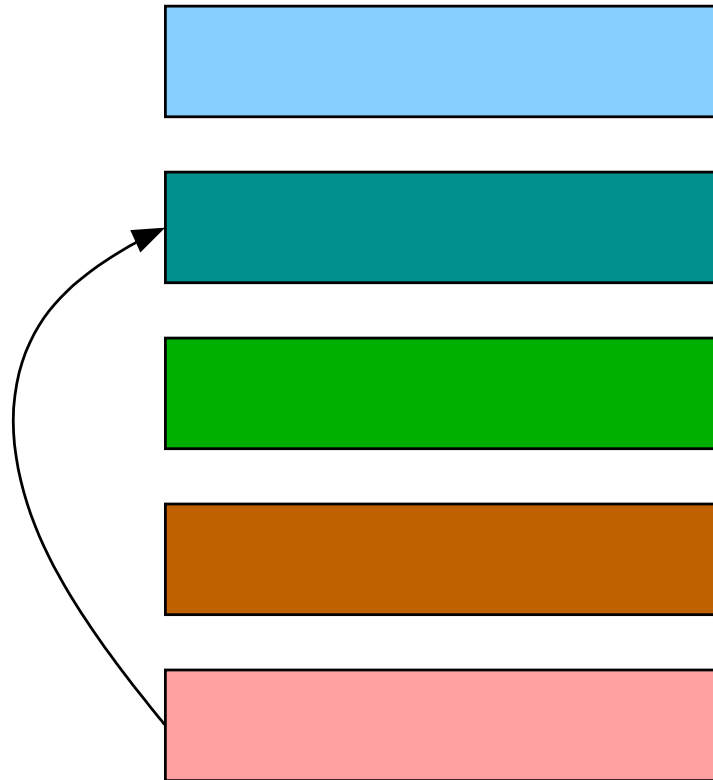
Inter-Layer Interactions (1)

- **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



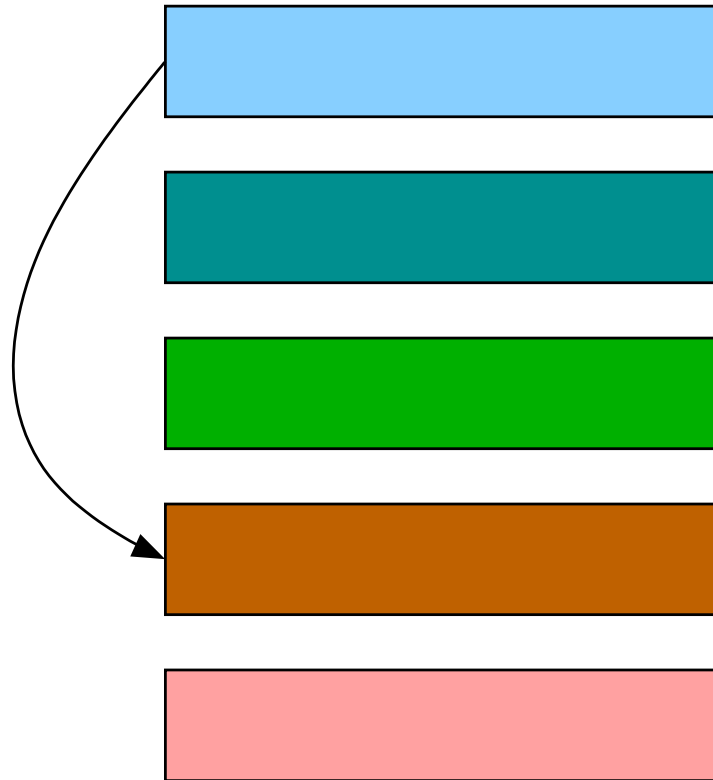
Inter-Layer Interactions (2)

Upward information passing



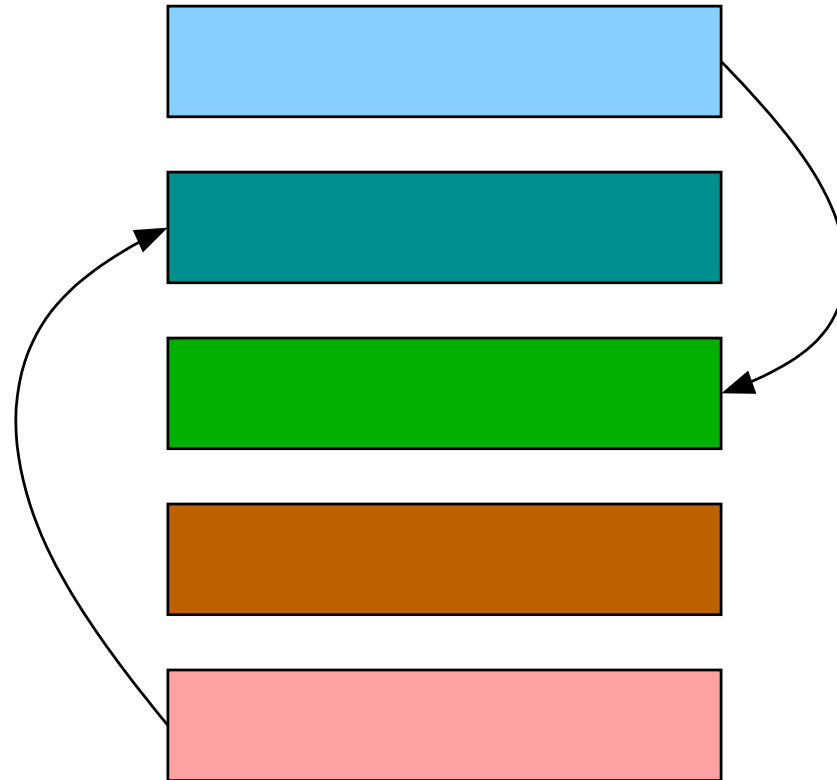
Inter-Layer Interactions (2)

Downward information passing



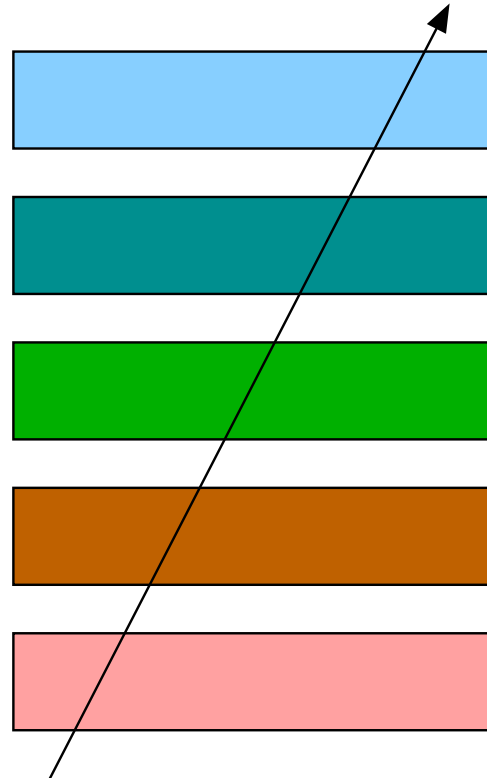
Inter-Layer Interactions (2)

Up-and-down information passing



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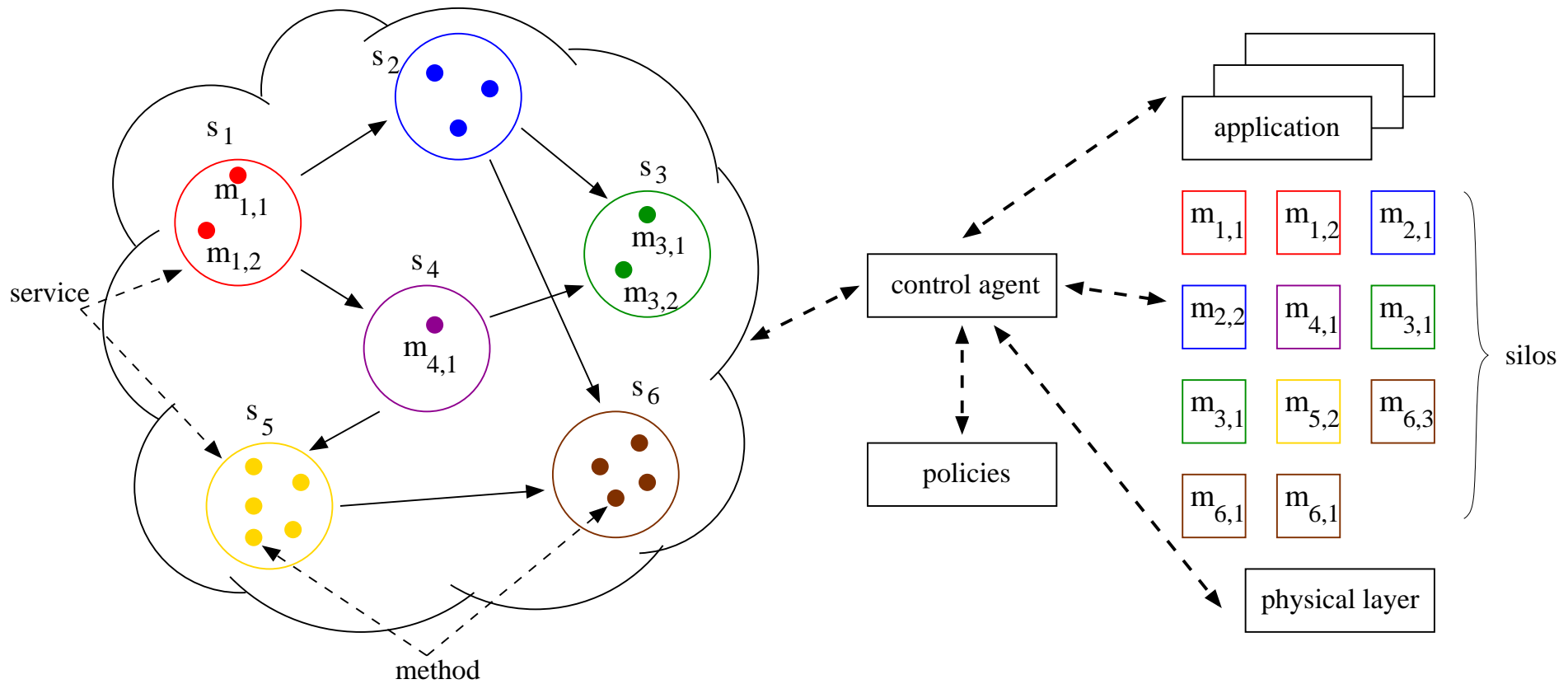
Silo-wide optimization/calibration



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

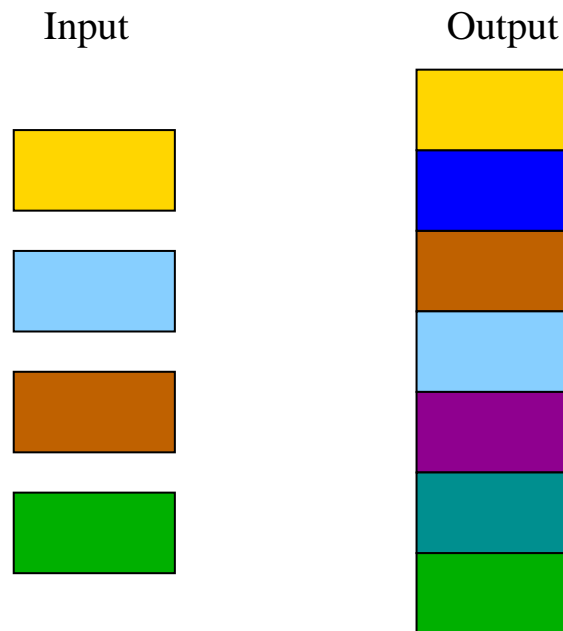


Service Composition

- 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

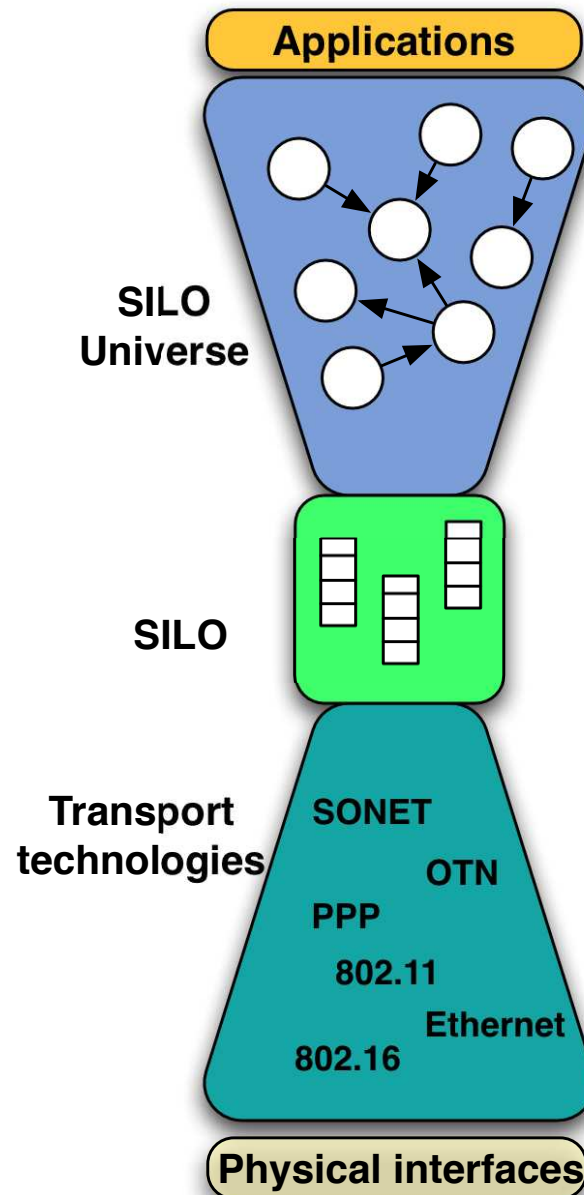
Service Composition Problem

- 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

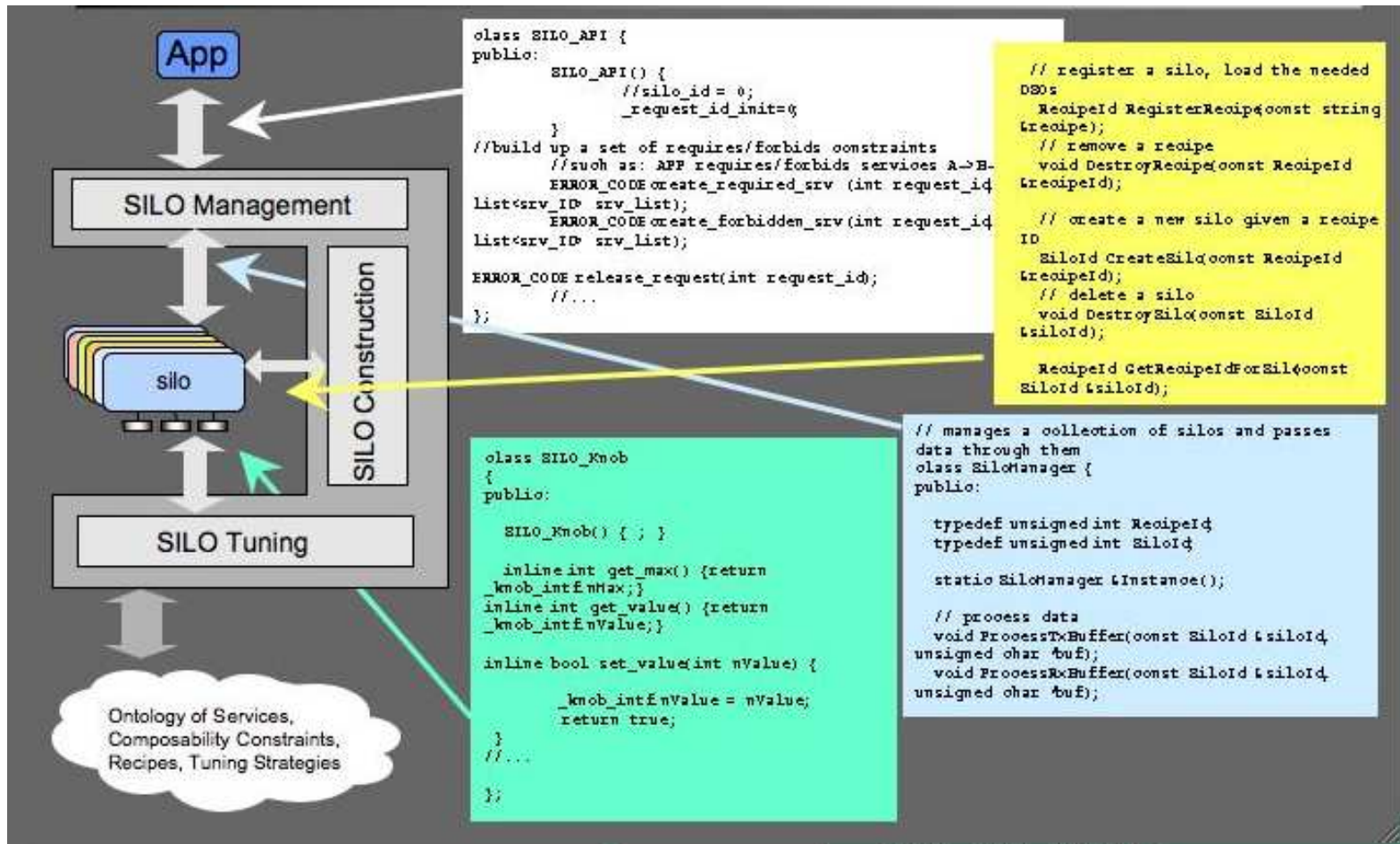


The SILO Hourglass

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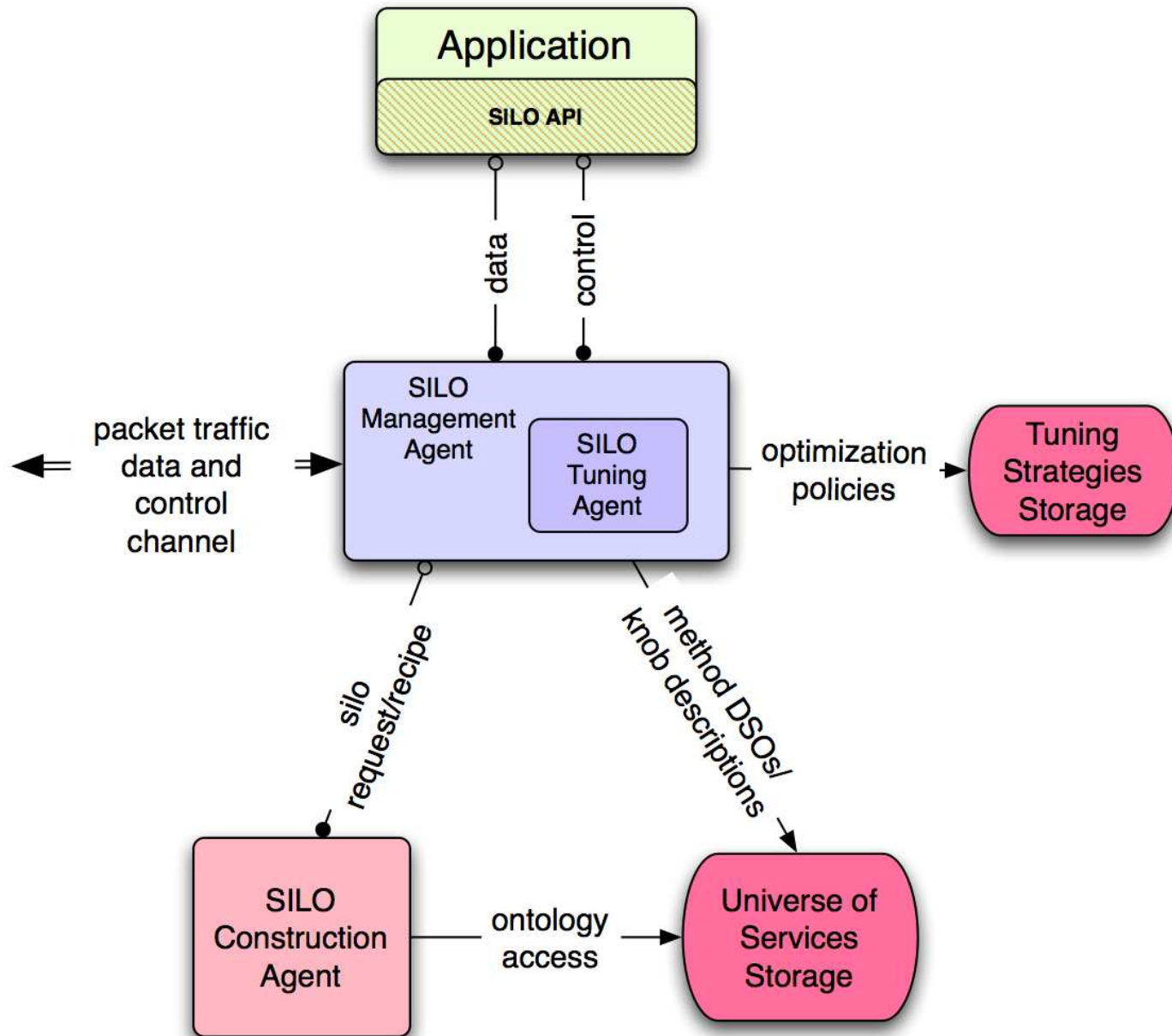


SILO Software Prototype

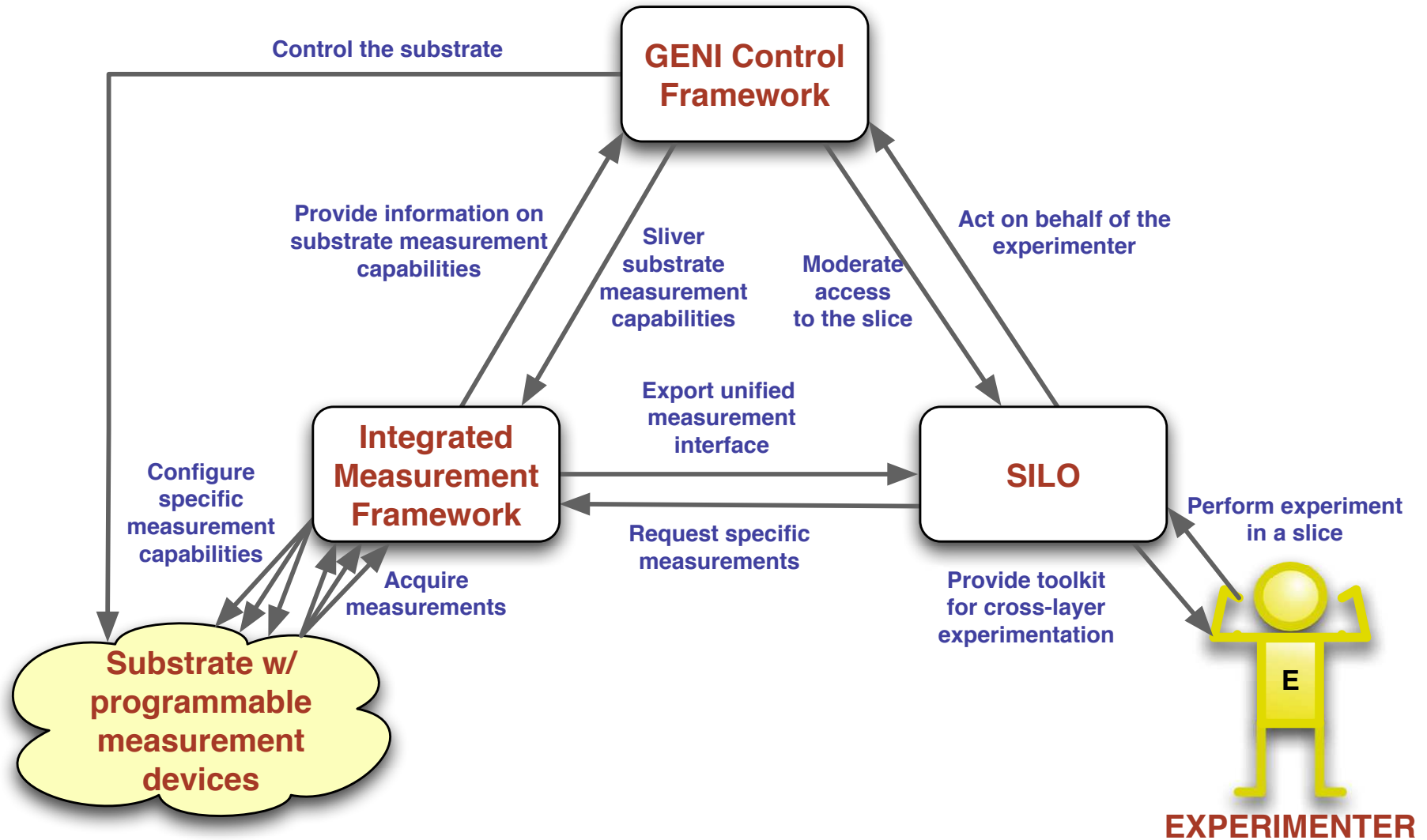


<http://net-silos.net/>

Prototype Architecture



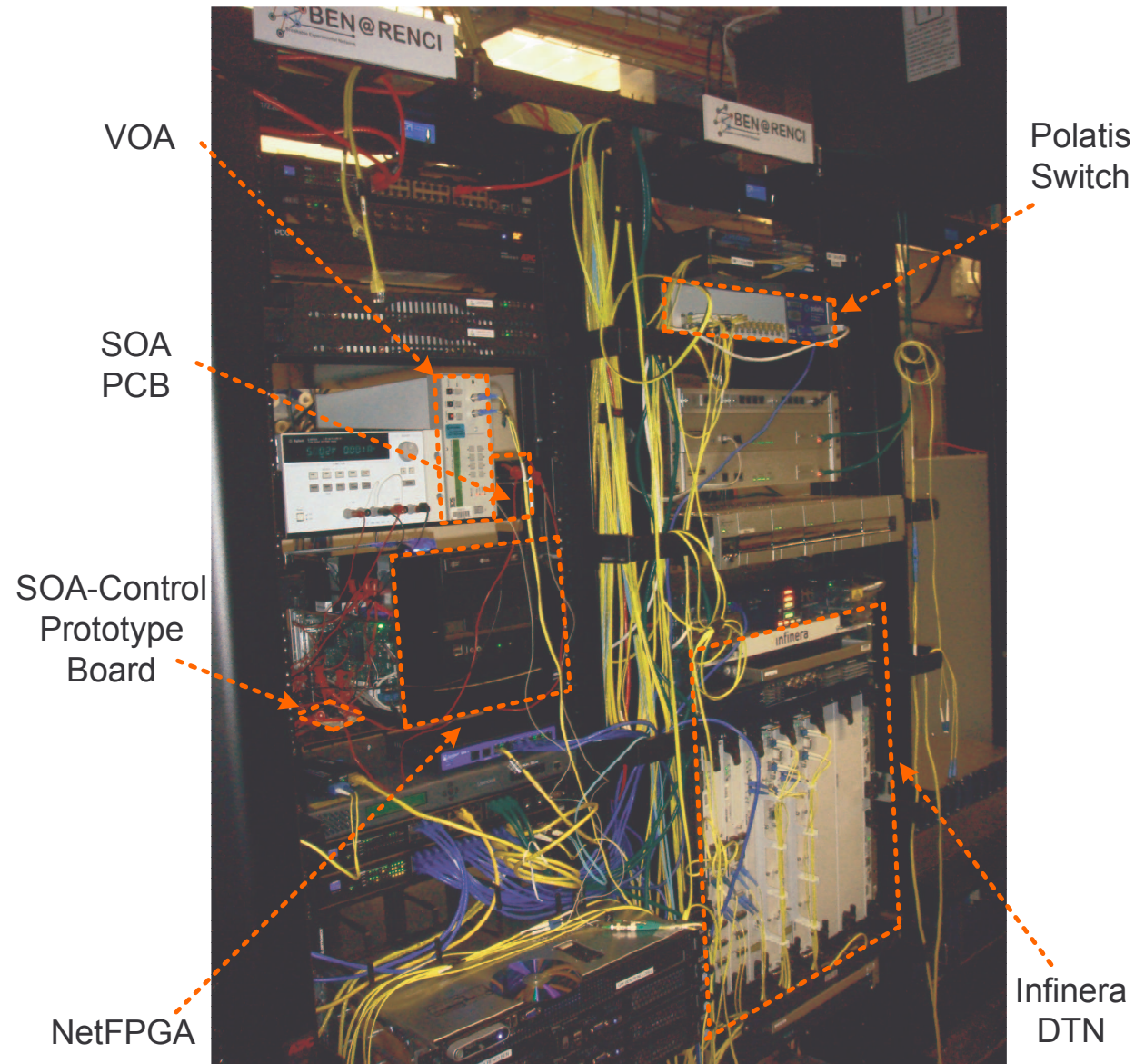
SILO As a Research Tool



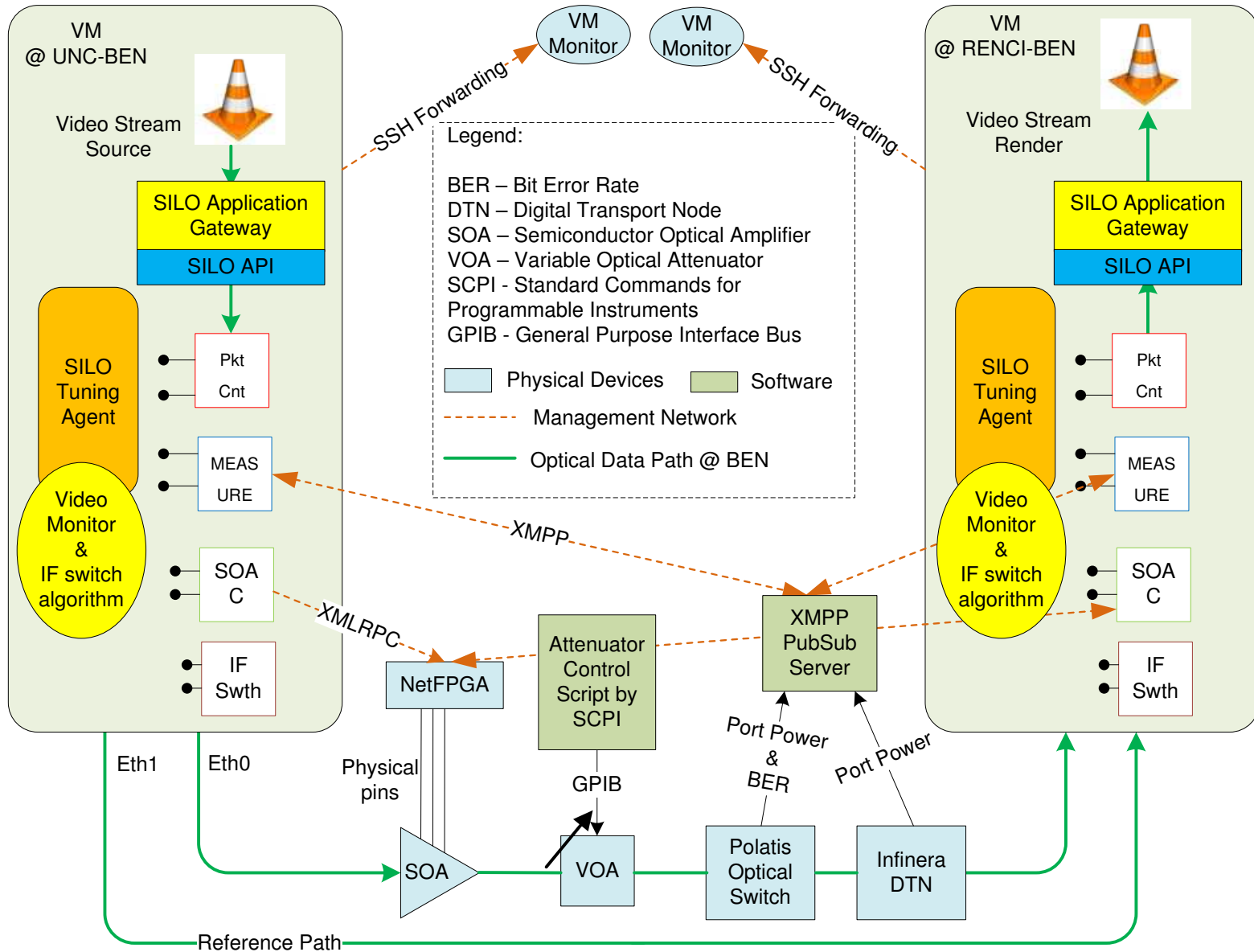
SILO As a Research Tool

- Deploys in a slice
- Researcher brings:
 - custom services
 - tuning algorithms
 - ontology updates
- Connect to measurement framework → cross-layer protocol experimentation tool

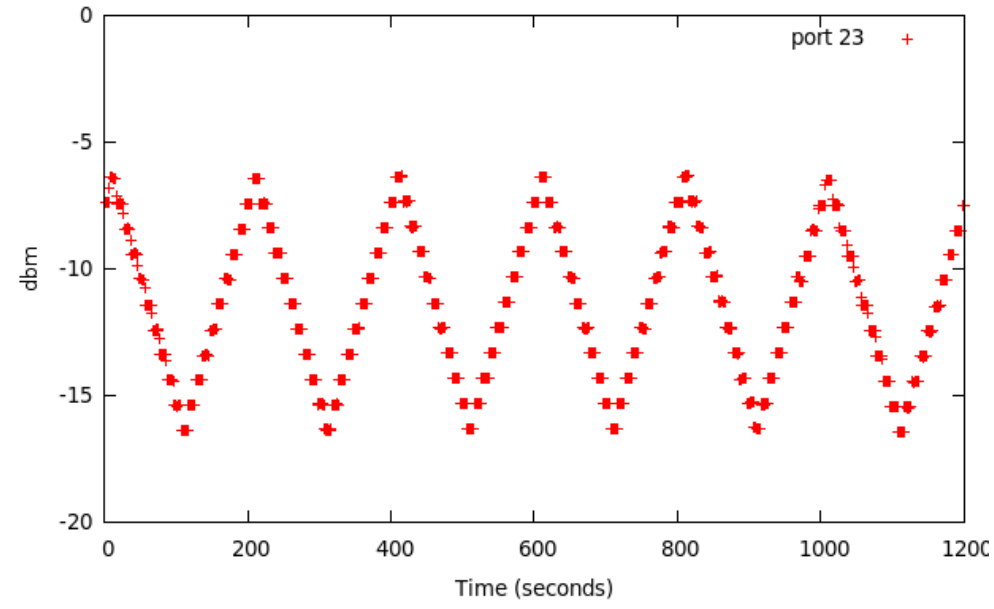
IMF Physical Infrastructure



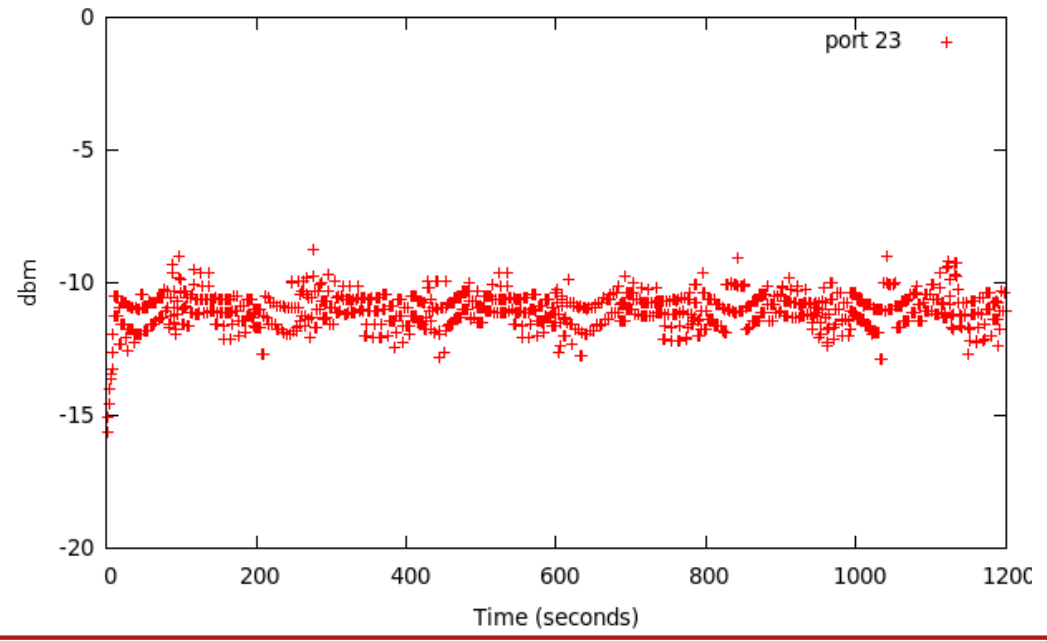
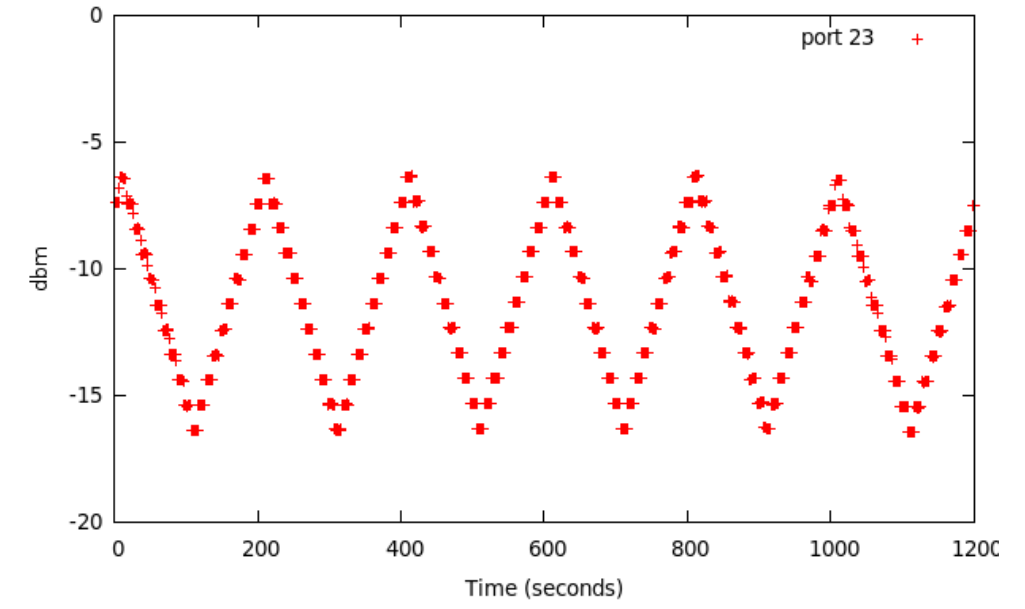
IMF Cross-Service Demo



IMF Demo – Results



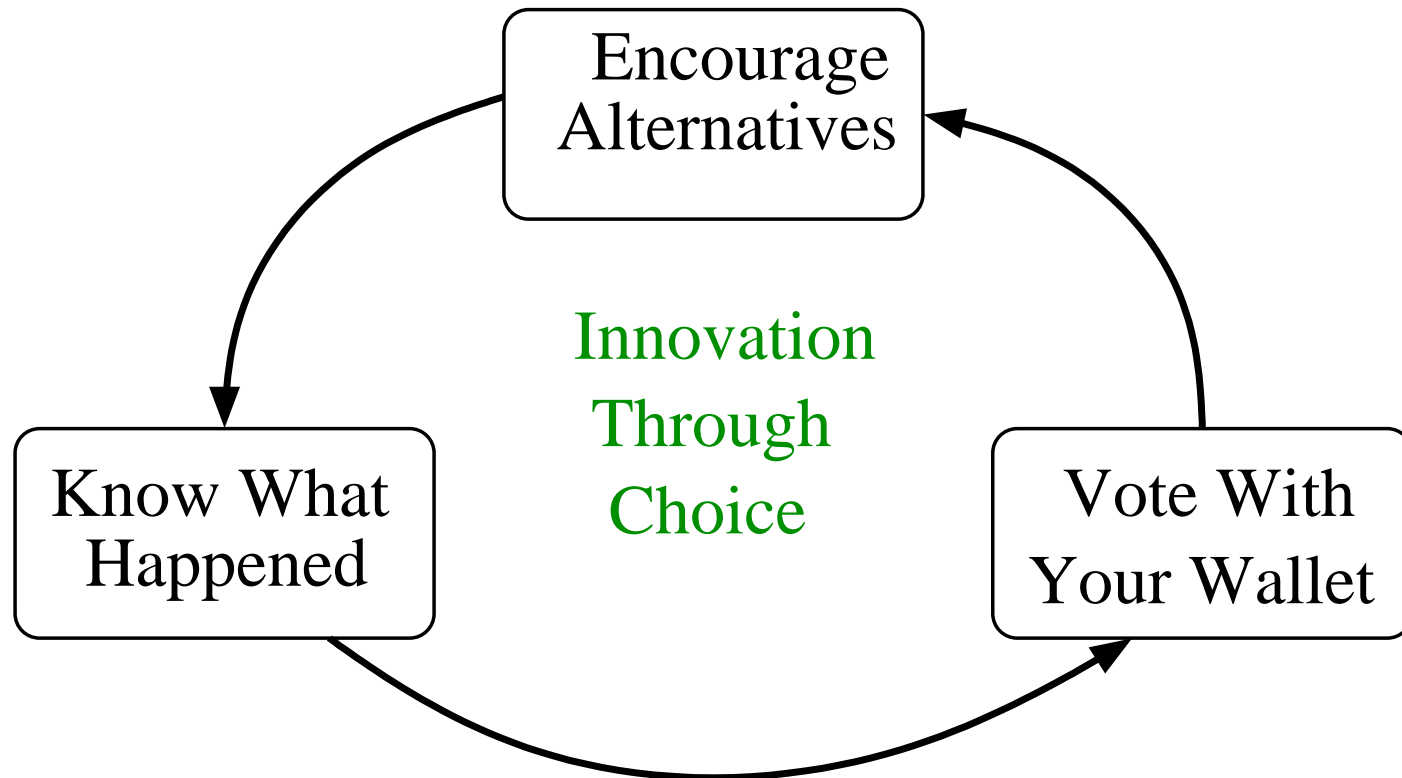
IMF Demo – Results



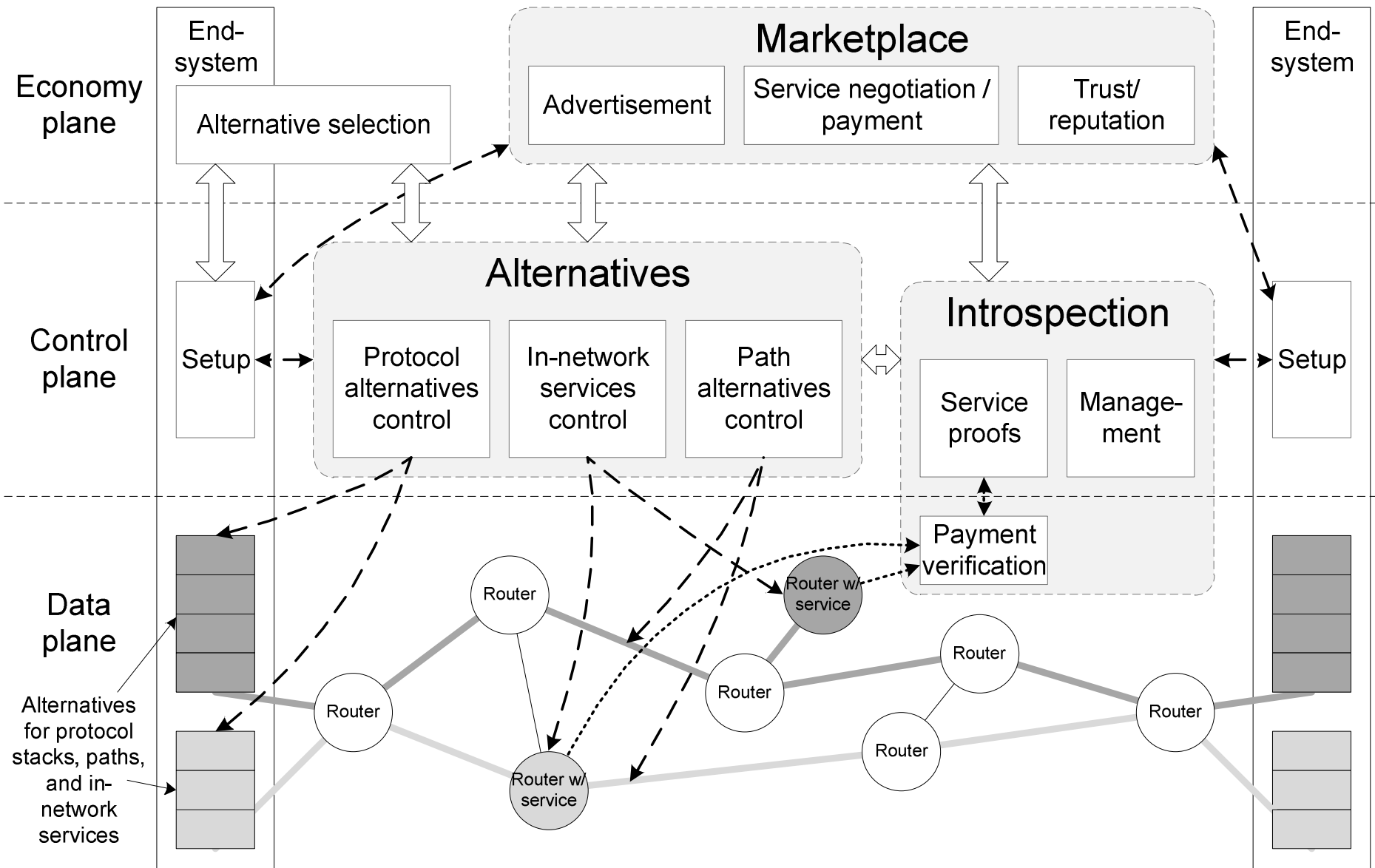
ChoiceNet: Design for Choice

- **Choice** a key aspect of a network architecture
 - drive transformative innovations
- New features and mechanisms for:
 - dynamically introducing new alternatives
 - selecting among alternatives
 - introducing economic processes and incentives to trigger innovation

ChoiceNet: Key Principles



ChoiceNet Aspects in a Network



Recent Book

