Planes for the Internet

Seminar in Distributed Computing
ETH Zürich

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About a Vision…

Motivation

- Increasing reliance on IP networks
- Increasing complexity of IP networks

→ Increasing needs for better techniques to manage them

Overview

- Motivation
- Existing Planes
- A Clean Slate Design
- Sophia: An Information Plane
- The Knowledge Plane
- Conclusion

Today's Existing Planes

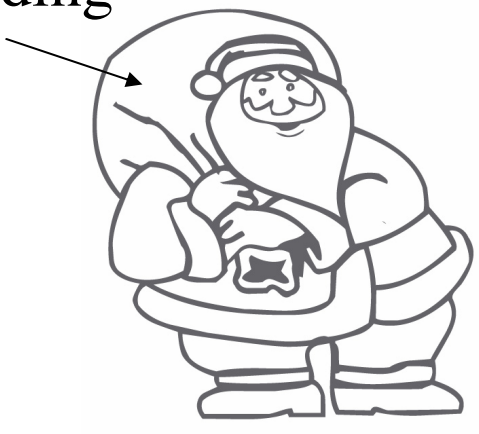
- Data Plane
  - handles individual packets
- Control Plane
  - implements the distributed routing algorithm
- Management (Mgmt) Plane
  - monitors the network
  - configures Data Plane mechanism and Control Plane protocols

Existing Planes
Difficulties

- Today's IP Planes far more complex

  For example: Data Plane's implementation

next-hop
forwarding



next-hop forwarding,
tunneling, access control,
address translation, queuing

Existing Planes
Difficulties

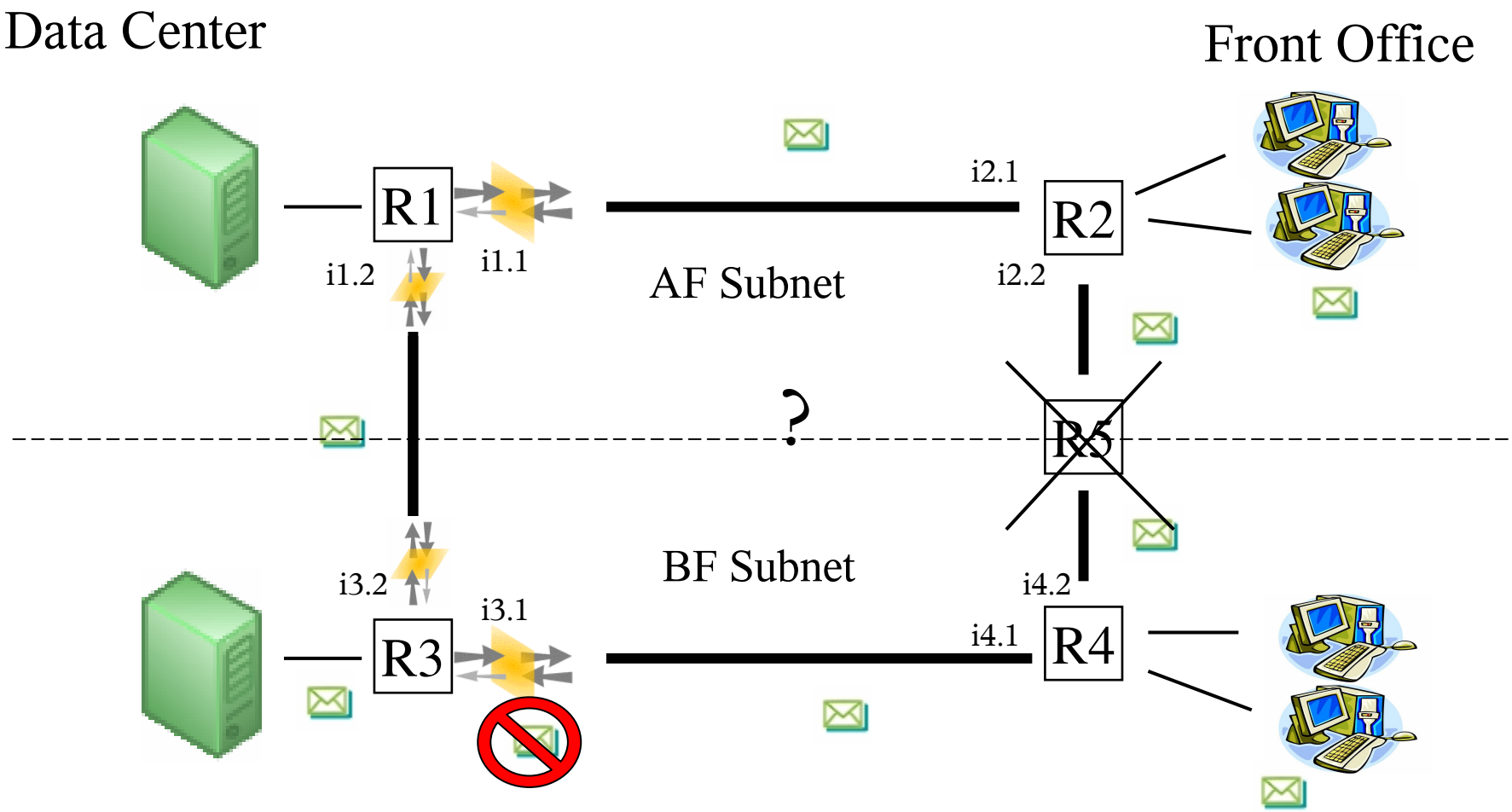
- States configured by multiple entities
- Dependencies between the states and the logic updating the states

  (not maintained automatically)
- A change to any part of the configuration can easily break other parts

  → fragile and complex network

Difficulties

Example – Reachability Control



Existing Planes
Real Example

- Just a made-up case?
- 24 hour Blackout of Major Microsoft Web sites (January 2001)

  Reason: improper configuration of router by a technician
- Large breakdown of Swisscom Backbone network (3 weeks ago)

  official reason: DDoS Attack

  hearsay: improper configuration

Existing Planes
Real Example

"One misconfigured router or unforeseen event can take down a network. It has to do with architecture, but there are a lot of unknown things that happen."

Keith Lowry,
vice president of security operations
for network consulting firm Pilot Network Services

A Clean Slate Design

A Clean Slate Design
Design Principles

- Network-level objectives
  - Today: objectives expressed in low-level configuration

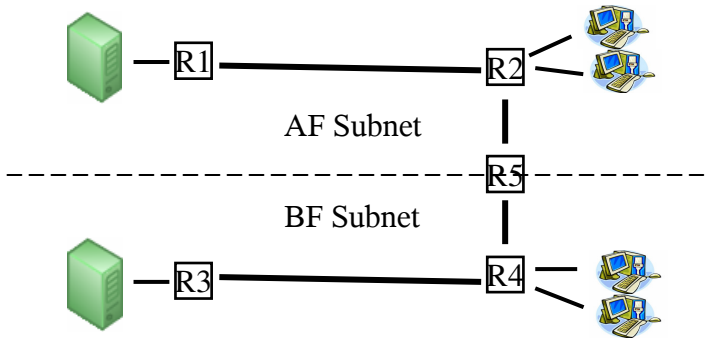
    → error-prone!!!
  - Principle: Objectives should be expressed separately from network elements

A Clean Slate Design
Design Principles

- Network-level objectives
  - Objectives concerning performance, reliability and policy

    for example: Reachability Control

    "Do not allow hosts in subnet BF to access the accounting servers in subnet AF"



A Clean Slate Design
Design Principles

- Network-level objectives
  - Purpose: abstraction → a robust network

A Clean Slate Design
Design Principles

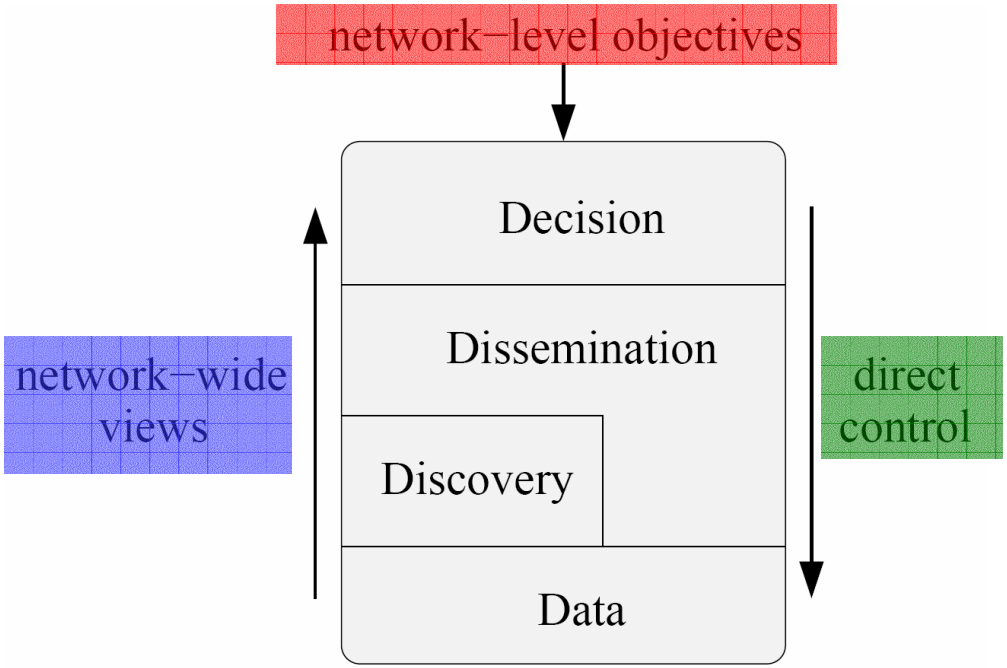
- Network-wide view
  - Today: measurement support added as an afterthought
  - Principle: coherent snapshot of the state of each network component
  - Time and space dependant
  - Information about topology, traffic, events
  - Purpose: a robust network

A Clean Slate Design
Design Principles

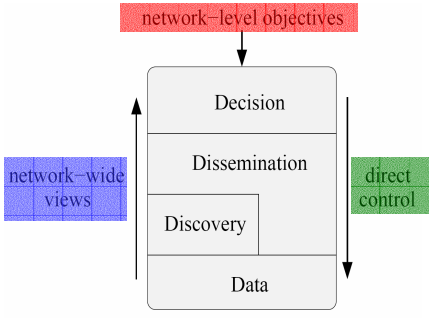
- Direct control
  - Today: Mgmt Plane has only indirect control over the network
  - Principle: only Control and Mgmt system responsible for setting all states of the Data Plane
  - No decision logic should be hardwired
  - Purpose: meet Network-level objectives

A Clean Slate Design Proposal

- Propose 4 Planes to achieve these objectives
- Extreme design point: Mgmt and Control decisions made in a logically centralized fashion

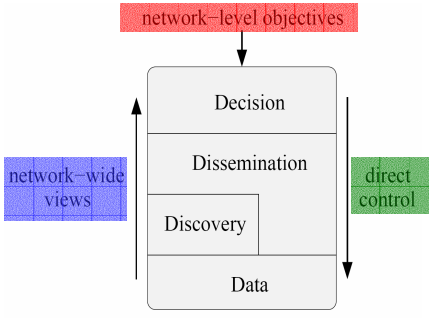


A Clean Slate Design Proposal

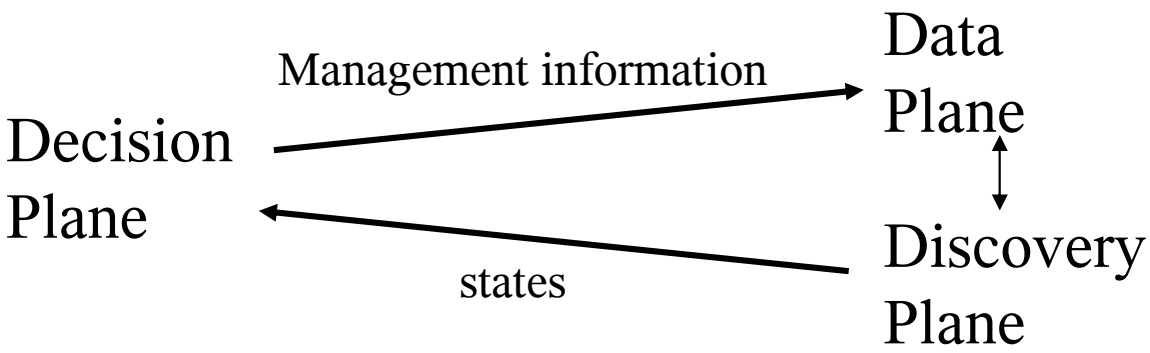


- Decision Plane
  - makes all the decisions (reachability, load balancing,…)
  - needs Network-wide view
  - uses standard algorithms to turn Network-level objectives into packet-handling state

A Clean Slate Design Proposal

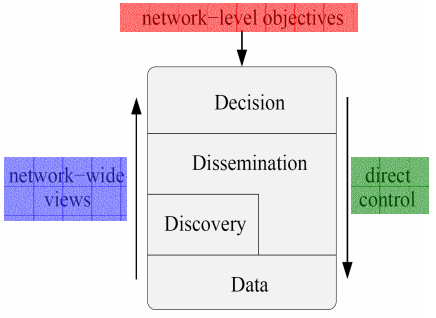


- Dissemination Plane
  - Communication substrate



  - Dissemination paths independant from data path

A Clean Slate Design Proposal



- Discovery Plane
  - Discovery of physical components and their relationships
  - creates identifiers to represent them
- Data Plane
  - handles individual packets

    (based on state given from Decision Plane)

A Clean Slate Design
Design Principles reached?

- Network-level objectives

  Decision Plane satisfies network-level objectives 

- Network-wide view

  Decision Plane operates on network-wide view 

- Direct control

  Decision Plane has direct control over the operation of the Data Plane 

A Clean Slate Design Evaluation

± Complexity

± Robustness

± Security

Solving or creating problems?

Or moving problems?

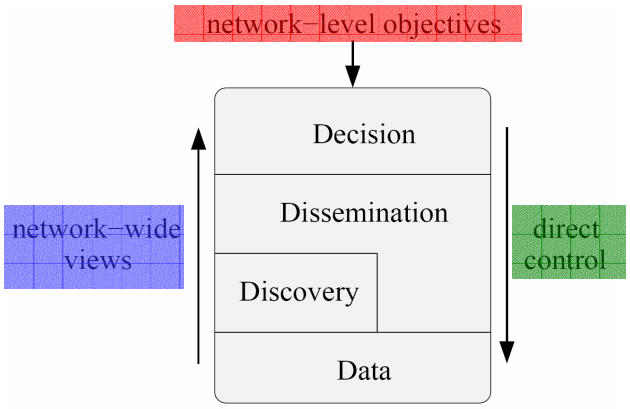
Sophia
An Information Plane

Sophia
An Information Plane

- A distributed system
- incorporates 3 functions
  - Collecting information about network elements
  - Evaluating statements about network's state ←
  - Reacting according to conclusion drawn

Set of sensors

Set of actuators



Sophia
Building a Network-wide view

- Goal: make statements about the overall network state and behavior
- uses Prolog
  - + No a priori assumption about possible states of the system
  - + Programms and data are equivalent
- Time and location explicitly part of every term

```
eval( bandwidth( env(node(id42),
                     time(1057766930)),
                 81920) ).
```

Sophia
Network-wide view - Performance

- Caching introduced
  - Tradeoff between most up-to-date value and computation latency
  - Ability to specify evaluation times in the past
- Scheduling
  - Ability to specify evaluation time in the future

Sophia
Network-wide view - Performance

- Evaluation planning
  - Analogy: Query planning in database systems
  - May be better to evaluate some expressions at some specific locations and times because of dependencies
  - Can rewrite original expression to obtain many components which can benefit from separate planning

Sophia
Evaluation

+ Distributed
+ Explicit introduction of time and space
+ Appropriate use of declarative programming language
– Incomplete model

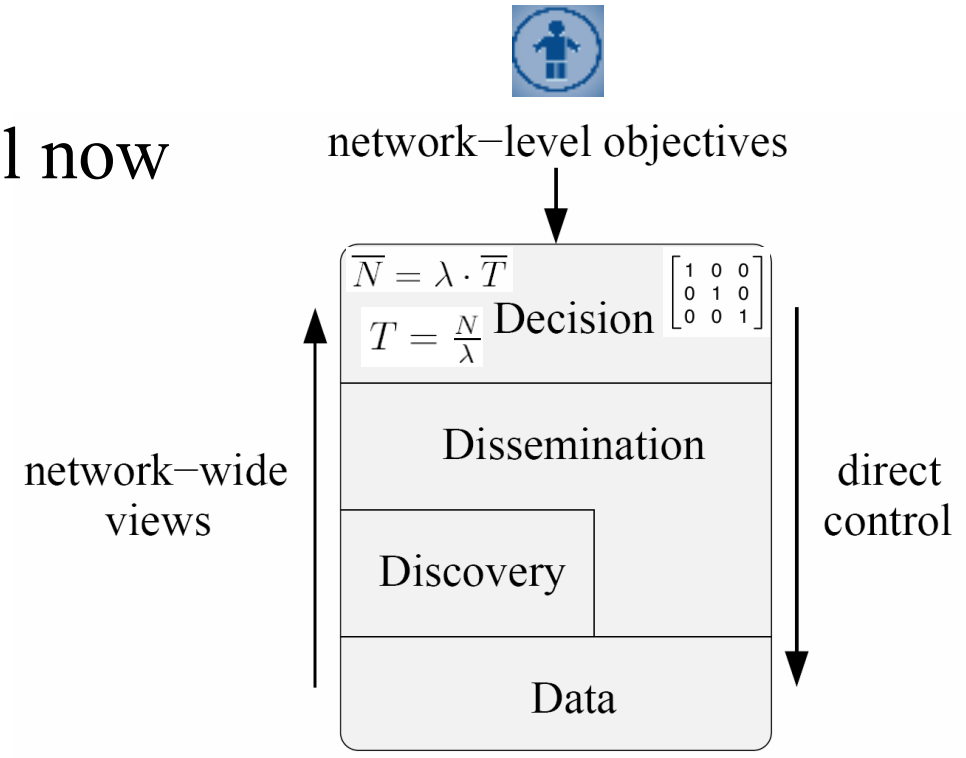
→ **a good distributed query processing engine**

- Claimed to be an incarnation of the Knowledge Plane for PlanetLab…

The Knowledge Plane

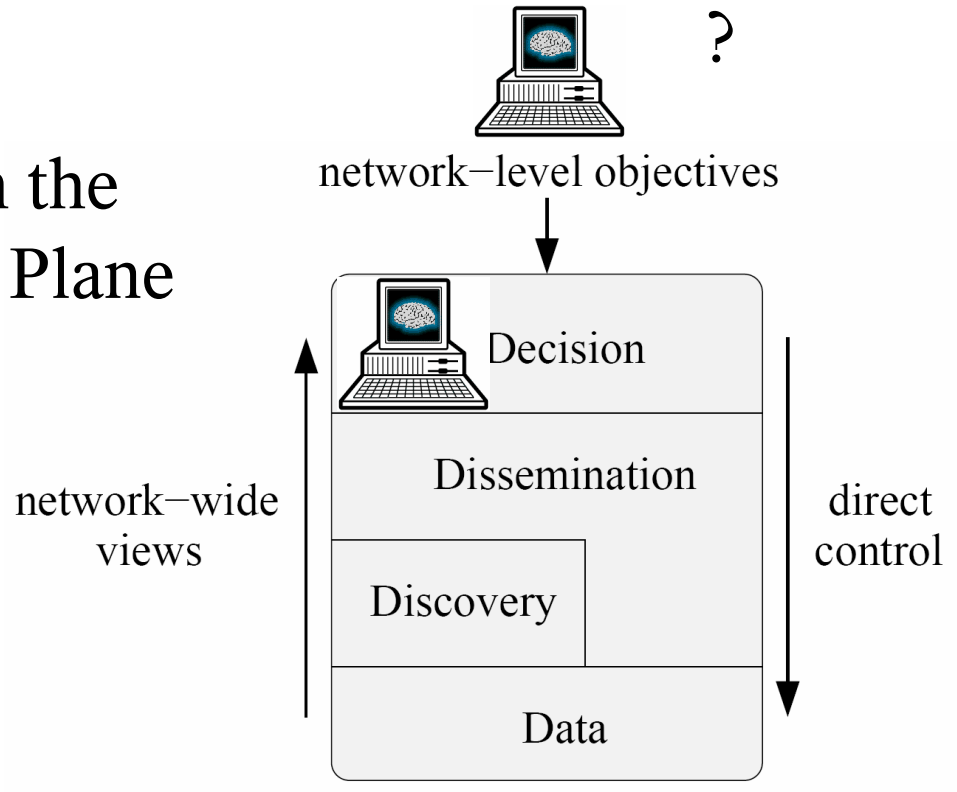
The Knowledge Plane Overview

Picture until now



The Knowledge Plane Overview

Picture with the Knowledge Plane



The Knowledge Plane
Possible Attributes

- In common with Sophia and the Clean Slate Design:
  - Network-wide view
  - Unified approach
  - Sensor-Actuator principle
- New:
  - Explicit encoutering for compositional consideration

    example: merging perspectives and activities of two previous unconnected networks

The Knowledge Plane
Possible Attributes

- New:

  Knowledge produced, managed and consumed at or beyond "traditional" edges of the network

Sufficient?

Source: Niko Matsakis

The Knowledge Plane
Possible Attributes

- **New:**
  - **Cognitive Framework**
    - foundation of the Knowledge Plane
    - operates effectively in the face of generality (in face of new technologies, new applications)
    - makes judgement in presence of partial or conflicting informations

The Knowledge Plane
Possible Attributes

- **New:**
  - **Cognitive Framework**

    - recognizes and mediates conflicts in policies and goals

    - performs optimizations, too complicated for humans, in high-dimensional environments

The Knowledge Plane
Why a Cognitive System?

- Traditional algorithmic approaches to adaptivity are unlikely to provide the required level of sophistication
  - Because they require:
    - complete information (in general)
    - precise problem formulations
    - relatively static environment

The Knowledge Plane Characteristics

- The Cognitive Systems (CS) should be able to …
  - … learn and reason:
    - CS improves when new situations are recognized, new actions performed:

      the knowledge base grows in useful ways
  - … gain experience and trust:
    - CS is ultimately able to recognize problems and to act on its own

The Knowledge Plane
An Architecture?

- Speculative ;-)
- Relevant points:
  - Distributed
  - Constraint driven (system may adopt any behavior which is not specifically constrained)
  - Bottom-up (composition/decomposition of simple entities to/from complex entities)

The Knowledge Plane
Evaluation

***AI*?**

- A way to handle the complexity of networks (?)
- Representing knowledge is already difficult
- Reasoning about it even more difficult
- Would need cognitive performance outperforming human capabilities

Looking at actual state of AI…

Very unlikely

The Knowledge Plane Evaluation

***AI*?**

"Artificial intelligence is overrated. We find most people prefer the user-friendly advantage of artificial stupidity."

The Knowledge Plane
Evaluation

- ***Conflict handling***?
- Implies a model of trust and persistent robust expression of identity
- Do we know who we are?
- Will one day a computer know who it is?

  Who to trust?

  Looking at today's politics and society complexity…

  utopic

The Knowledge Plane Evaluation

- Work at a very high-level of abstraction (the right one?)
- Courage of addressing unavoiding issues
  - Who would control this unified system?
  - Are traditional algorithms able to handle such complexity?

Conclusion

- Visions about new solutions for network's control & management
- Unified approaches proposed
- Criticism against actual state justified (?)
- Solutions not (fully) successfuls
- An intelligent network or a stupid network managed by intelligent human beings?

Thanks for your attention

References

- "A Clean Slate 4D Approach to Network Control and Management “, A. Greenberg, G. Hjalmtysson, D. A. Maltz, A. Myers, J. Rexford, G. Xie, H. Yan, J. Zhan, and H. Zhang
- "Sophia: An Information Plane for Networked Systems", M. Wawrzoniak, L. Peterson, and T. Roscoe

References

- "A Knowledge Plane for the Internet", D. D. Clark, C. Partridge, J. C. Ramming and J. T. Wroclawski
- http://www.news.com/Internet-companies-begging-for-attack,-experts-say/2009-1001_3-251622.html
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Reactions – Questions ?

- About Science or Science fiction?
- Which idea(s) would you keep?
- Which idea(s) would you throw away?
- A vision or a nightmare?