Future Internet and its multiple dimensions

Future Internet Cluster Meeting
Stockholm - June 11, 2008

Dimitri Papadimitriou

Alcatel-Lucent BELL NV

dimitri.papadimitriou@alcatel-lucent.be

Outline

- Introduction
- Dimensions
- Key Technology Challenges
- Design Objectives
- Design Principles
- Recommendations

Introduction

Internet evolution is a multi-dimensional equation with multiple tradeoffs

[Functionality x Performance x Complexity x Cost]

Most fundamental principle of the Internet: **Occam's razor principle** "*plurality should not be posited without necessity*"

-> Simplicity principle (KISS) = robustness through simplicity - "*a trade-off can be made between simplicity of interactions and looseness of coupling*"

Implications:

1. Highly converged approaches are less efficient than less converged solutions
2. Network at scale of today's Internet -> simplest possible solutions to build cost effective infrastructures

"*The evolution of protocols can lead to a robustness/complexity/fragility spiral where complexity added fo robustness also adds new fragilities, which in turn leads to new and thus spiraling complexities*" -- J.Doyle

Dimensions

1. Common technological challenges = problem statement

→ **Scope**: narrow e.g. TCP/IP (and related networking aspect e.g. routing) vs large scope (physical (?), network, mediation, application)

- note: can only be expressed wrt current knowledge / perception we have -

2. **(Design) objectives**

Starting from the **existing Internet design objectives** vs **tabula rasa** (rebuild the Internet design objectives)

- note: this may subsequently impact the design principles, models and components -

3. **Approach**

Incremental (evolutionary: improve / add new / remove from existing design principles, no architectural model breakthrough) vs **disruptive** (revolutionary: architecture re-build from scratch, may lead to new design principles and new model(s)

- note: this may subsequently impact the design models and components -

Note: dimensions are often mixed together because of the inter-dependency

Key Technology Challenges (networking space)

Security
- Intrusion detection
- Denial of service (DoS)
- Spam, worms, etc.

Accountability
- User → network accountability (user accountable for resource usage)
- Network → user accountability (Internet delivering what user expects)

Manageability and diagnosability
- Configuration and upgrade cost
- Address and routing information management
- Problem detection and root cause analysis

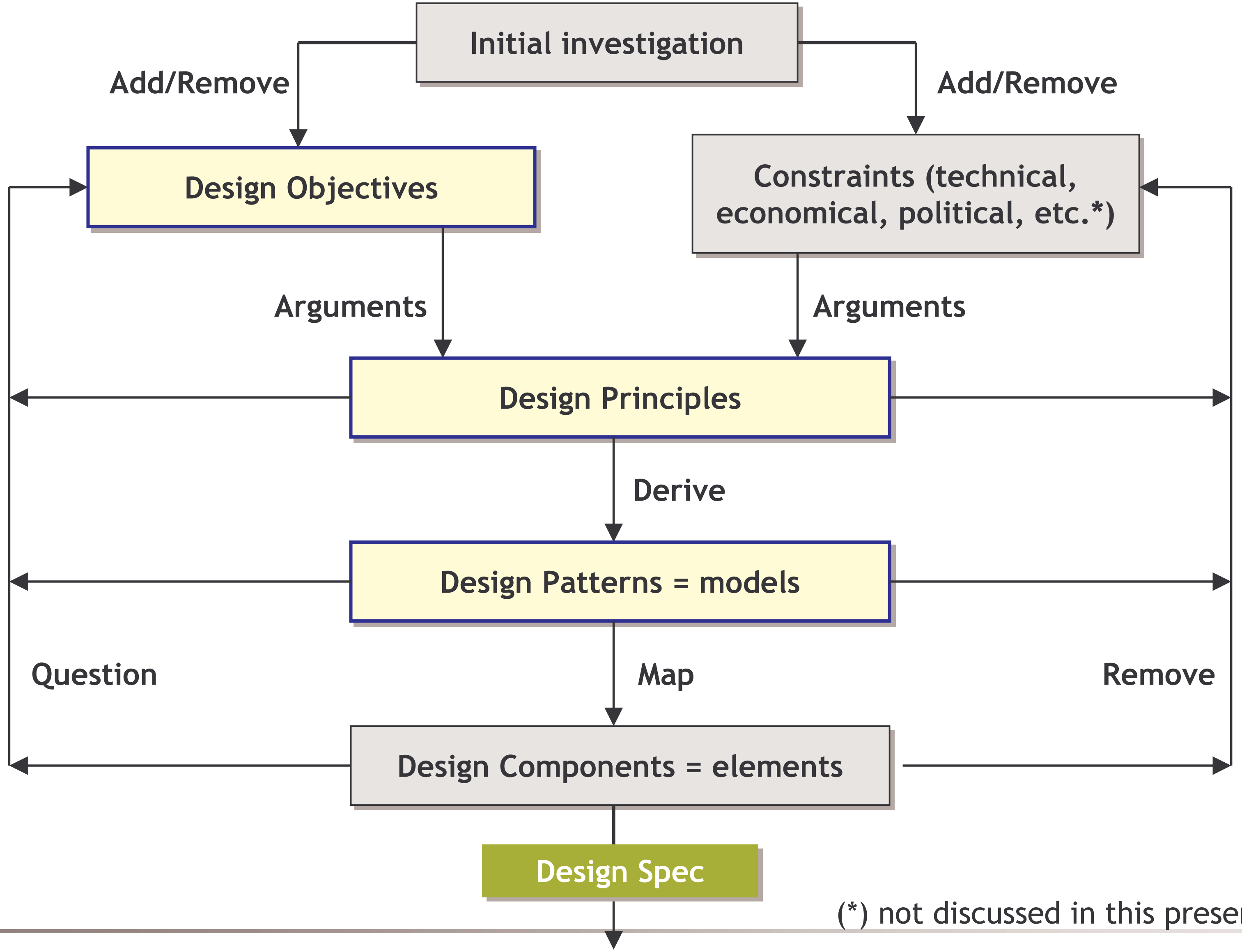
Availability (maintanability and reliability)
- Monitoring and measurement
- Resiliency against normal accidents and failures
- Fast recovery/resiliency of routing system

Routing system scalability
- Supra-linear scalability (e.g. beyond Shortest-Path First ~ n log n, stretch = 1)
- Addressing architecture (topology dependent vs topology independent)
- Routing system dynamics (stability/robustness, and convergence properties)

Mobility
- Wireless access: losses interpreted by TCP stack as congestion
- TCP connection continuity: IP address as network identifier vs host identifier

Holistic Architecture

Process



(*) not discussed in this presentation

Design Objectives

Some of these properties are met by current Internet others not

Functional

- Accountability
- Security
- Manageability, and diagnosability
- Availability (reliability, and maintanability)
- Mobility, and Nomadicity
- Accessibility (*), and Openness
- Transparency
- Neutrality

(*) depends on the geographic region

Architectural

- Scalability
- Evolvability (>< Ossification)
- Flexibility (e.g. support multiple socio-economic models, operational models)
- Heterogeneity (e.g. wireline and wireless access technologies)
- Simplicity
- Robustness
- Survivability, and Resiliency
- Distributed, and Automated control
- Autonomous (organic deployment)
- Genericity (application independence, traffic e.g. streams, messages, etc.)

Design Principles

Key architectural principles (current Internet)

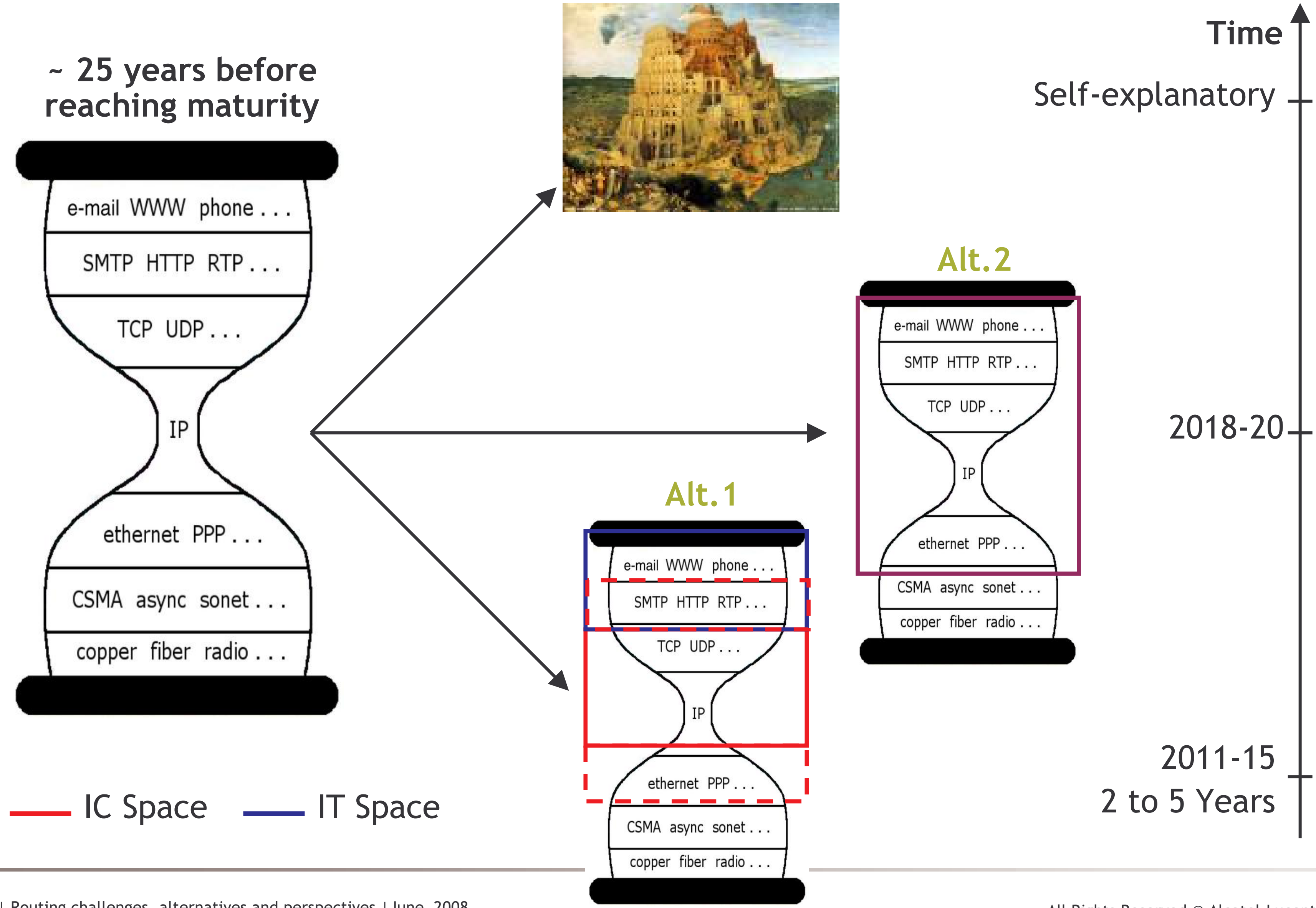
- **Modularization by layering**
- **Connectionless packet forwarding**
- **Network of collaborating networks (interconnection via IP gateways = routers)**
- **Intelligent end-systems**
- **End-to-end principle/argument - fate sharing**
- Loose coupling principle
- Simplicity principle (Occam's razor principle)
- Locality principle (local cause(s) shall result in local effects)

Which new design principle(s) - some key principles under investigation:

- Cognition (-> autonomous and automated adaptation)
- User-network cooperation (-> resolve sub-optimal user performance/utility)
- Applicative mobility

In addition to applicability analysis of existing principles (-> in depth analysis required)

Design models: Two serious alternatives (scope- and time-dependent)

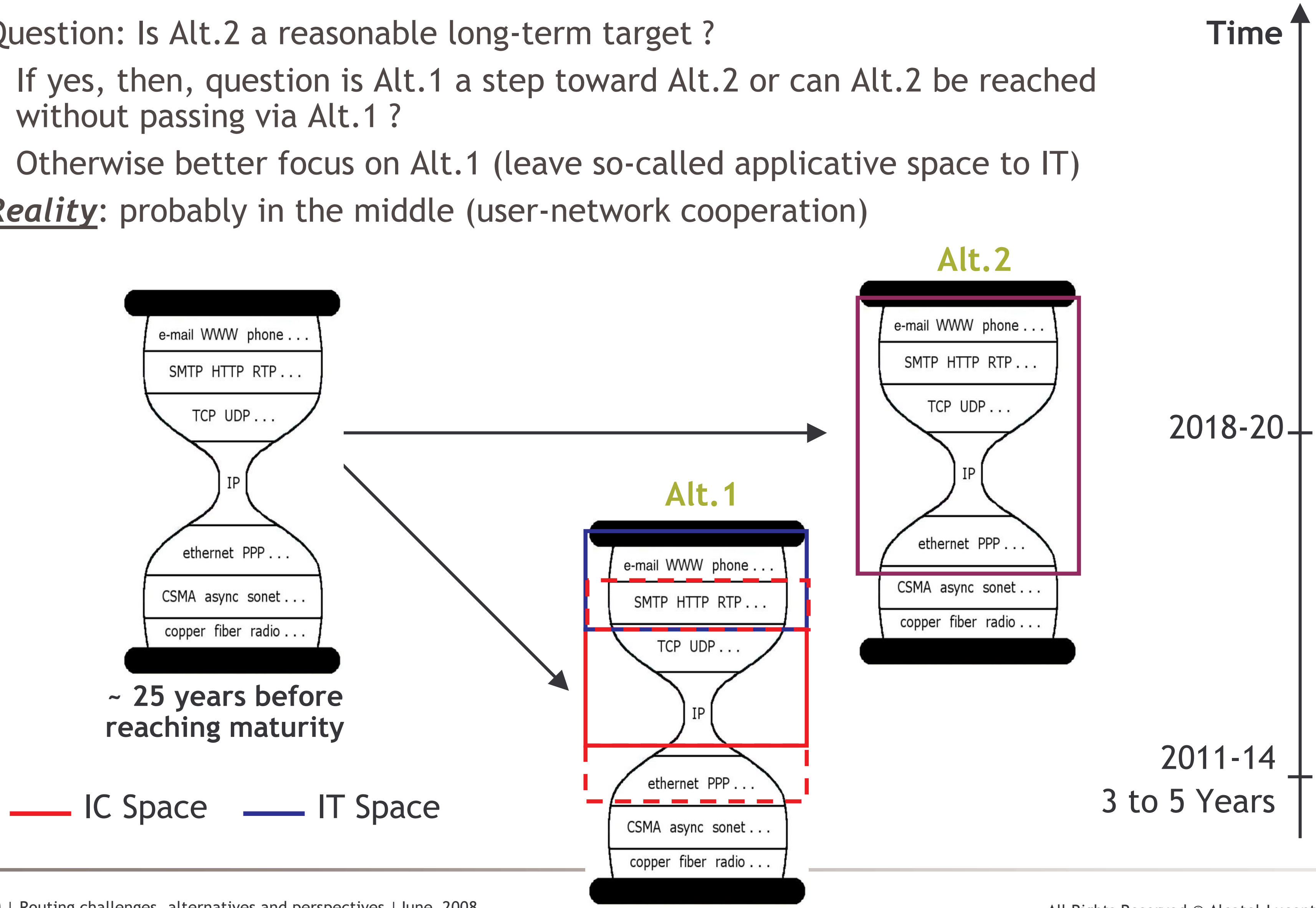


Design models: The real questions

Question: Is Alt.2 a reasonable long-term target ?

- If yes, then, question is Alt.1 a step toward Alt.2 or can Alt.2 be reached without passing via Alt.1 ?
- Otherwise better focus on Alt.1 (leave so-called applicative space to IT)

Reality: probably in the middle (user-network cooperation)



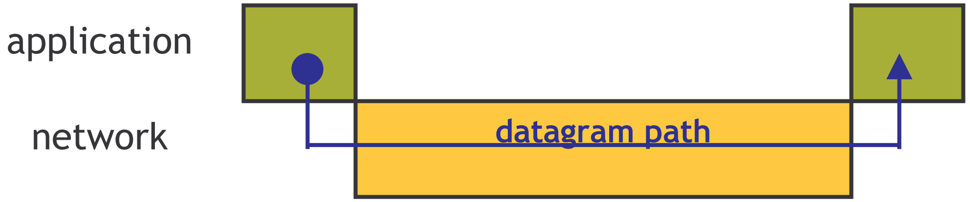
Example: routing / overlay routing problem space

→ Solution

1. Either circumvent technological and operational limits of existing network layer in particular shortcomings of IP layer routing (in terms of scalability, stability, convergence but also sub-optimal user performance)
2. Or build an (infrastructure-based) overlay on top of existing IP network layer = add an additional layer of indirection and/or virtualization with benefits (such as customization) but also side effects
    1. Change properties in one or more areas of underlying network
    2. Horizontal and vertical cross-layer conflicting interactions impacting overall network performance (amplified by selfish routing)
    3. Genericity, evolvability, scalability, stability, convergence, etc.

Future Internet - Design Models

Internet model (user stateless network): limited and not adapted (anymore) to user/ applicative needs

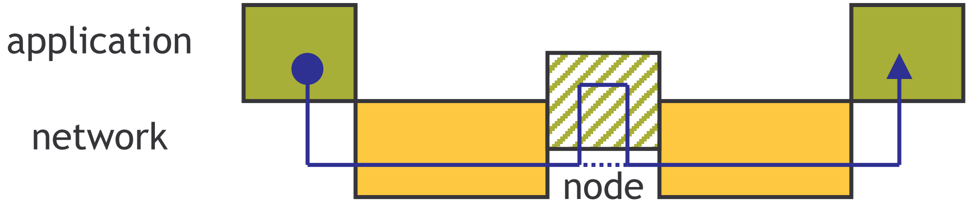


#Host = N>>n

#Nodes = n (resource sharing)

Network nodes support n states

Application-aware networks (user statefull): unscalable unreliable, unsecure and unflexible (prevents new application development)



Network nodes to support N states: one state per applicative flow

Future internet (possible) model: user-network cooperation (network-aware hosts)

Network nodes to support n states

Approaching the problem space (1) - Recommendations

In networking most low-hanging fruits have been consumed

Concepts historically borrowed from stochastic theory, fluid theory, graph theory, etc.

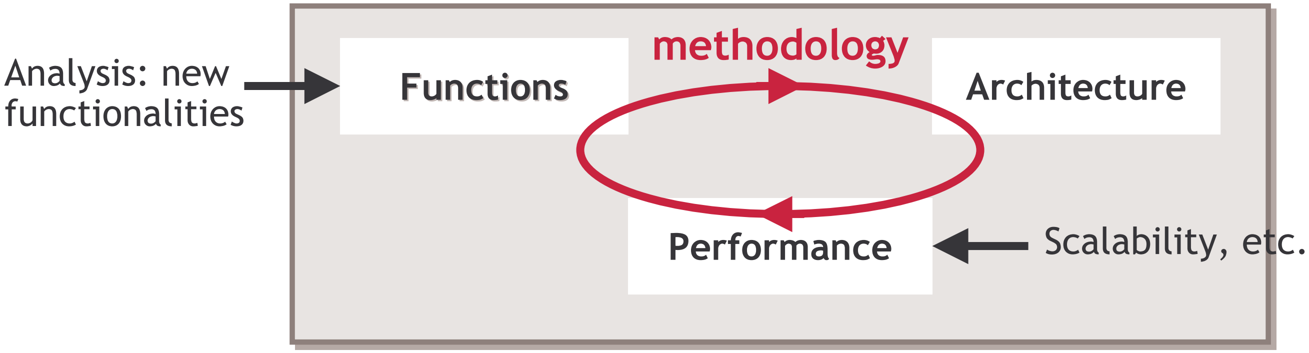
⇒ **Cross-fertilization:** cross-domain and cross-discipline research

Structuring efforts before coordinating efforts

⇒ Work on **functions** (translating design objectives) before deriving detailed future internet **architectural components** (focus on design principles and models)

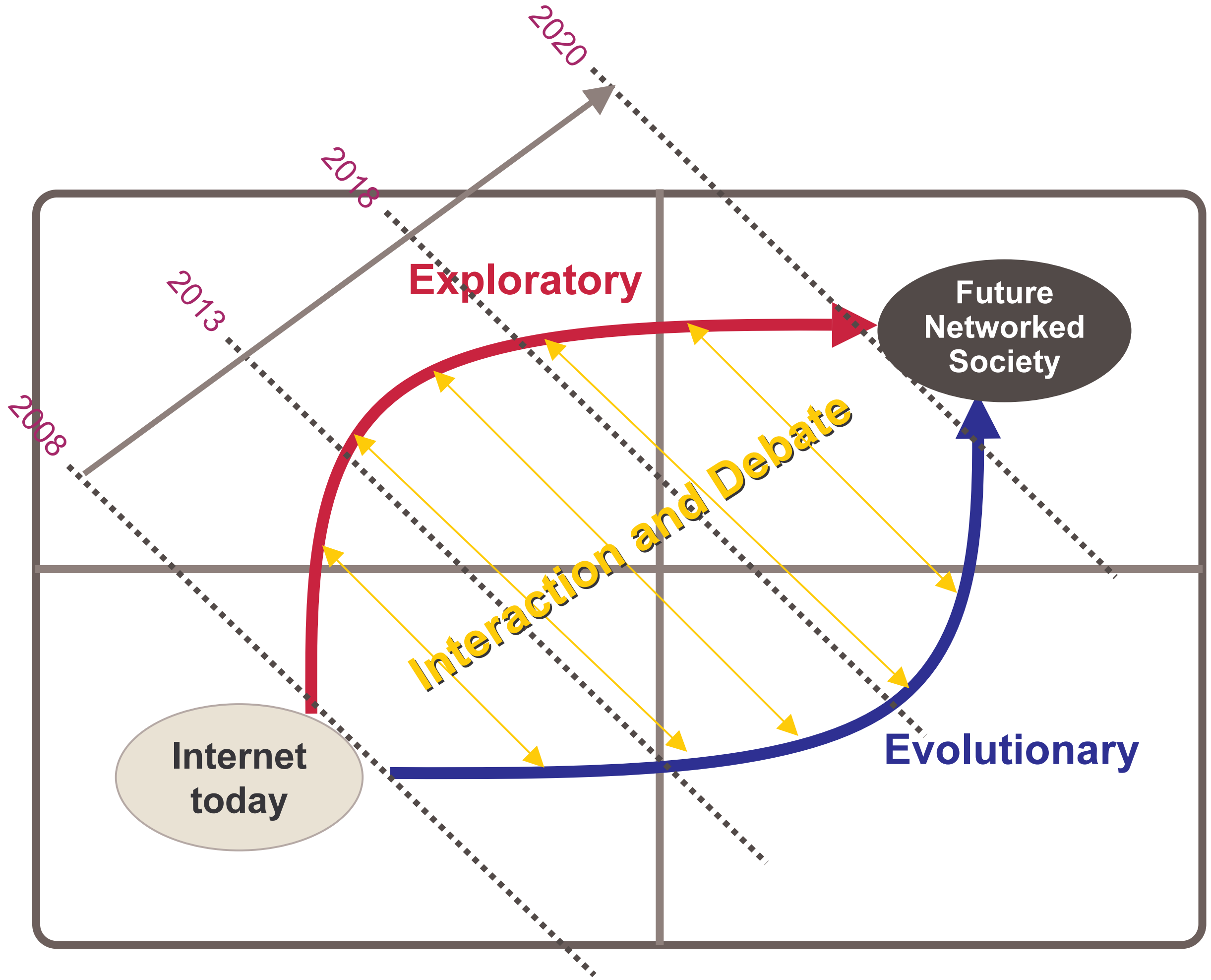
Experimentation, realization and sustainable large-scale deployment (to everyone(*) is as important

⇒ **Cross-methodology**: theoretical (top-down) x experimental (bottom-up)



(*) not interested by a niche techno with limited deployment

Approaching the problem space (2) - Trajectories



Recommendations:

- Recognize importance of evolutionary & exploratory paths
- Build trajectories along both paths toward common challenge (vision)
- Development of phased agendas over time

-> **Interaction and debate needed** (to make paths and visions meeting in common challenge)

-> **Build common cooperative space** (with involvement of all actors: academic, industrial, etc)

Note: dates are indicative of timeframe

Exploratory vs Evolutionary Approach

Both approaches addresses the same problematic and themes but…

Evolutionary: no architectural breakthrough (innovation in context of current Internet architecture)

- Non-disruptive evolution of current architecture & technologies
- Future Internet challenges may be addressed separately
- Certain level of backward compatibility (at design phase)
- Deployability taking into account current Internet conditions and constraints (at least partially) -> migration path

Exploratory: architectural breakthrough (referred to as clean-slate)

- Define a new Internet architecture from scratch that would provide for a better global solution (addressing Future Internet challenges as a bundle)
- Disruptive innovation not impacted by existing install base/technologies
- Feasability in the context of large-scale experimental facilities

Investigation space: evolution vs exploration

	Networking - Infrastructure	Mediation	Application - Superstructure
Evolution of existing paradigms, principles and components	Forwarding Routing (scalability & security) Congestion control TCP and beyond	Accountability (feedback)	Sensor/Ambient Home/Domestic Vehicular/Industrial Video e.g. UHDV, 3D
New paradigms, principles and components	Cognition Autonomy and Automation	Cognition User-network cooperation	Cognition Social networks 4D (time) Application mobility
Fundamental science	Quantum physics Biology/virology/etc. Neurology	?	?

Evolutionary   Exploratory

Note: research on physical layer (photonic and radio) is not strictly coupled to the Future Internet

Recommendations

1. EU actors at large (academic and non-academic) must learn from past experience (e.g. B-ISDN, ATM, etc.) as well as show maturity, common sense, and know-how ("think globally and act locally")

2. Scope as well as design objectives and principles must be sufficiently well defined and accepted ("rough consensus") so as to build design models and components from a common baseline

3. Cross-disciplinary and cross-domain research agenda resulting from this vision should lead to practical and sustainable realizations (experimental, industrial, … but not just paperwork) ("The best way to predict the future is to create it")

-> Do the right thing AND do the thing right

‘Pour être plus il faut s’unir,
pour s’unir il faut partager,
pour partager il faut avoir une vision.’
(Pierre Teilhard de Chardin)