

# ON THE FUTURE INTERNET

GRIF

Groupe de Reflexion sur l'Internet du Futur

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## SUMMARY

1. Context
2. The Future of Networking
3. The Underlying Basic Research
4. The Creation of Value in Networking
5. How to Meet the Challenges

## I. Groupe de Reflexion Internet du Futur

### ■ Steering Committee

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- D. Kofman, Institut Télécom

### ■ Report not yet public

## II. THE FUTURE OF NETWORKING

- The global network allowing the convergence of various new network paradigms
  1. New types of core networks
  2. New types of access networks
  3. Spontaneous wired and wireless networks
  4. Sensor and agent networks
  5. New network contents
  6. New network services

### III. THE UNDERLYING TYPES OF RESEARCH

- Basic research common to all these new paradigms
  1. Architecture
  2. Technologies
  3. Internet mathematics
  4. Internet measurements and statistics
  5. Internet algorithms
  6. Internet economic models
  7. Network and service platforms

## NETWORK ARCHITECTURE

- Basic Internet architecture: addressing, routing, congestion control
- Further primitives: security, mobility, QoS, management
- Distribution of intelligence between CPE, network and services
- New paradigms:
  - Autonomic network management
  - Application aware networking

## NETWORK MATHEMATICS

- Network modeling, managing complexity:
  - Fundamental laws on network dynamics and control
  - Ultimate capacity of self-organized wireless networks
  - Traffic characterization
- Network simulation
- Tools: probability, statistics, control, information theory, signal processing, graph theory

## NETWORK METROLOGY

- **Traffic statistics:** emerging applications, trends
- **Internet probing:** end-to-end measurements
- **Network inference:**
  - traffic matrices,
  - detection of anomalies, attacks.

## NETWORK ALGORITHMS

- **Wide range of computer science tools:**
  - **distributed algorithms** consensus, election, epidemic diffusion
  - **resource management algorithms:** resource allocation, scheduling
  - **data base algorithms:** content storage, update and retrieval, content replication, consistency.
  - **search engines, semantic web**

## NETWORK ECONOMICS/SOCIOLOGY

- New economic models:
  - open networks,
  - location based services
- Economics of interconnection, security,
- Sociology: social networks, application deployment

## NETWORK TECHNOLOGIES

### ■ Optics:

- new core networks with highly increased capacity and new concepts (e.g. optical burst switching);
- new access networks FTTH/FTTO (e.g. based on plastic optical fibers);

### ■ Radio: 100 Mbit/s interfaces before 2011 and 1Gbit/s after; new paradigms

- MIMO;
- cognitive radio;
- HF NFC technology for RFID.

## PLATFORMS

- Exploration and validation of new paradigms via
  - Shared clusters (Emulab)
  - Large network emulators (Planetelab, Onelab)
- In France, **GRID 5000**: shared experimental platform funded by various research institutions and universities.

## IV. ON THE CREATION OF VALUE IN NETWORKING

- Alcatel-Lucent → DSL
- However, the creation of value in Internet related companies originates in an important part from **disruptive SMEs stemming from Academia**.
  - Cisco-Stanford,
  - Google-Stanford,
  - Facebook-Harvard,
  - Qualcomm-UCSD.

## HOW TO FAVOR THE CREATION OF VALUE IN NETWORKING?

- Innovation in **Industry, SMEs, Startups**
- Collaborative National or European programs are often not well adapted to SMEs and to cutting edge research
- National and European programs should take this into account by creating
  - **Point to point interaction programs** focused on SMEs
  - More channels for autonomous **disruptive research**

## V. HOW TO MEET THE CHALLENGES?

- Build a couple of **Stanford-level universities** on networking in Europe.
  - Identify and strengthen **excellence centers** on networking in Europe capable of attracting the **top researchers/students**
  - **Excellence ought to be measured through impact**
    - \* In top international conferences (**ACM Sigcomm, IEEE Infocom**) and Journals (**IEEE ToN, JSAC** etc.)
    - \* In key standardization bodies (e.g. the **IETF**).

## NEW TYPES OF CORE NETWORKS

- Trends towards IP networks over simple, super-fast **optical core networks**
- Major challenges
  - **Architecture** for security, naming, new forms of routing,
  - **New paradigms**: semantic routing, virtualization (construction of optimized virtual networks answering the needs of a collection of users or applications)

## NEW TYPES OF ACCESS NETWORKS

### ■ Trends towards

- Wide variety of wireless access networks **3G/CDMA, LTE, WiFi, WiMax, Satellite**, etc.
- Development of **FTTH/FTTO**
- Development of **home networking**

### ■ Major challenges

- Improvement of **spectral utilization** (cognitive radio, ABC);
- **New economic models** (open access networks);
- Services based on **context and localization**;

## SPONTANEOUS NETWORKS

- Operator-less networks:
  - Self Organized wireless networks (e.g. **wifi meshes**)
  - Infrastructure-less wireless networks (e.g. **MANETS**)
  - Self Organized wired networks (e.g. **peer to peer**)
- Major challenges
  - **Vehicular and Navigation networks** (automobile, plane)
  - **Emergency/Military networks**
  - **New economic models** (multihop communication networks);
- Potentially strong **impact on economy and society** new business models

## INTERNET OF THINGS

- Trends towards
  - Interconnection of the Internet with the physical world through **sensors and agents**
  - Tagging of industrial production by **RFID**
- Major challenges
  - **New traffic and architecture challenges:** possibly hundreds of billions of new objects
  - New paradigms for **routing, search, naming, maintenance, data survival, etc.**
  - New services: **home, health, security, distribution, traffic, ecology, etc.**
- Very strong **impact on economy and production**
- Positioning in e.g. the EPC global network

## NEW NETWORK CONTENTS

### ■ Trends towards

- Diversification of the nature of transported contents: initially files, then real time games, video, telephony, white board. Then TV, VoD etc.
- Diversification of the localization of contents: each user becomes a content producer (peer to peer applications)
- New interactions with data: Web 2.0, semantic web.

### ■ Major challenges:

- Volume, distribution and heterogeneity of contents
- Respect of both IPR & individual freedom
- Content updating and obsolete content discarding
- Neutrality

## NEW NETWORK SERVICES

### ■ Trends

- Web of documents → web of services and web of knowledge.
- Explosion of new applications: SecondLife, FaceBook, or LinkedIn.
- More to come with augmented reality, virtual worlds, real time games, telepresence
- Search engines, semantic web
- Orchestrations of services

### ■ Major challenges:

- New business models
- Adapt/design network to/for new services