On the need for a research program in Internet Science

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Idea: On the need for “Internet Science”

- Problem
  - Research on Internet and networked applications is fragmented
  - Lack of thorough understanding of the complex interrelations
  - Lack of methods and tools to engineer future networks and applications
- Dimensions
  - Technology (networking and communications)
  - Service (seamless, ubiquitous communication)
  - Psychological (human-comp. interaction: usability, human behav.)
  - Social (communities, social web)
  - Economic (business models, cooperation incentives)
  - Political (regulation, standardization)
  - Energy (the ‘green’ agenda)
  - Security (relevant across all dimensions)

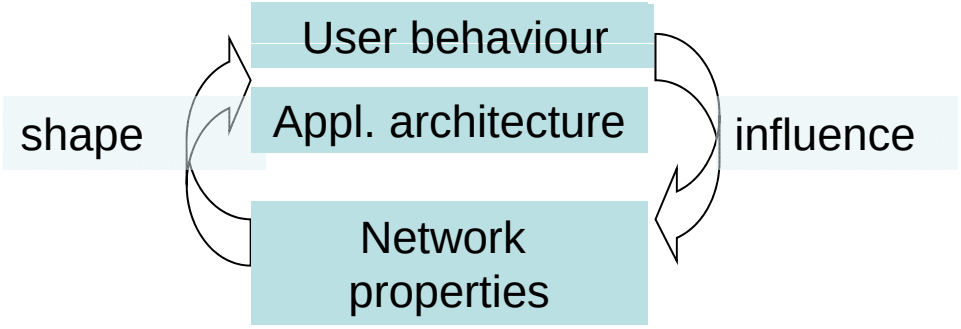
  Internet in the center of a highly complex system
- Combination of multidisciplinary approaches
  - Analytical: establish unifying theory and models
  - Empirical: measure and analyze network instantiations

  Analysis
  - Constructive: design innovative instantiations of the future Internet and its networked applications
  - Methodological: create and improve methods and tools for network engineering

  Engineering

Ambition: Internet Science

- Challenges
  - Developing a global theoretical framework that covers the actual heterogeneity and can include new networking paradigms / technologies
  - Control and management of the large, complex, global Internet
  - Adaptivity and evolvability that integrate future unexpected applications
  - Mobility at different levels
  - Resilience and survivability
  - Security and privacy
  - Policy boundaries and trust across administrative and political boundaries
  - Understanding of interactions while Internet evolution is ongoing
- Goal: unterstanding complex interactions, e.g.
  - interaction of user behaviour and network property
  - interaction of application architecture and network property



Vision, Opportunities and Risks

- *Tom Anderson, Larry Peterson, Scott Shenker, Jon Turner et al:*
  - *Actions arising from limitations:*
    - Minimize trust assumptions
    - Enable user choice
    - Allow for edge diversity
    - Design for network transparency
    - Meet application requirements
  - *Recommendations to the NSF:*
    - Experimental architectural research in networking needed
    - Foster experimental validation of this networking research
    - Fund the development and deployment of suitable testbeds
    - Substantially increase funding for new multi-disciplinary efforts
    - Promote synergy and convergence among architectural visions
    - Help the community (in disruptive architectures) learn from industry
- *Jon Crowcroft, Mark Handley, David Hutchison et al*
  - *Opportunities and risks:*
    - Vulnerabilities in networks and end-systems ⇨difficulty in preventing abuse of infrastructure and services
    - Complexity of networked systems configuration, leading to operational problems
    - Plurality of services ⇨ conflicting requirements on increasingly complex infrastructure
    - Explosive growth in application domains across all fields of human endeavour

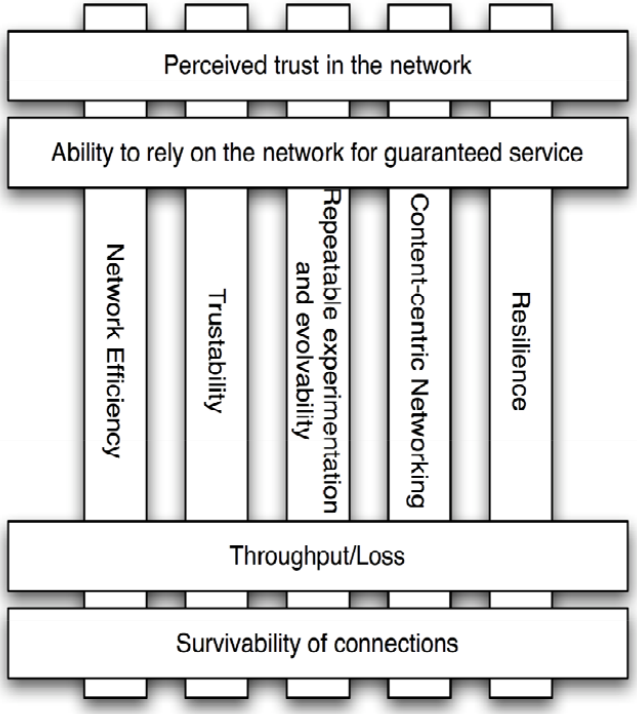
Impact: Internet is Critical Infrastructure for Society

- **Society**
  - For society that increasingly depends on Internet, “Internet Science” helps shaping evolution of society which increasingly depends on the Internet.
  - Changes the social inter-action of the society by enabling new services and applications
- **Sustainability** of networks and networked applications by
  - engineering methods that guarantee by design desired properties: energy-efficiency, resilience, security, privacy, anonymity
- The Internet and its services are a **critical infrastructure**
  - needed for growing number of non-critical and mission-critical applications
  - "the Internet is too big to fail"
  - lack on thorough understanding of instantiations of Internet is unstable basis for future; puts high risk on society and its evolution
  - Internet with all what's around it is a highly complex system, may react in totally unsuspected ways to random events, and therefore may fail or perform in an adverse way.
  - lack of methods for engineering Internet with desired properties hinders progress in many application areas

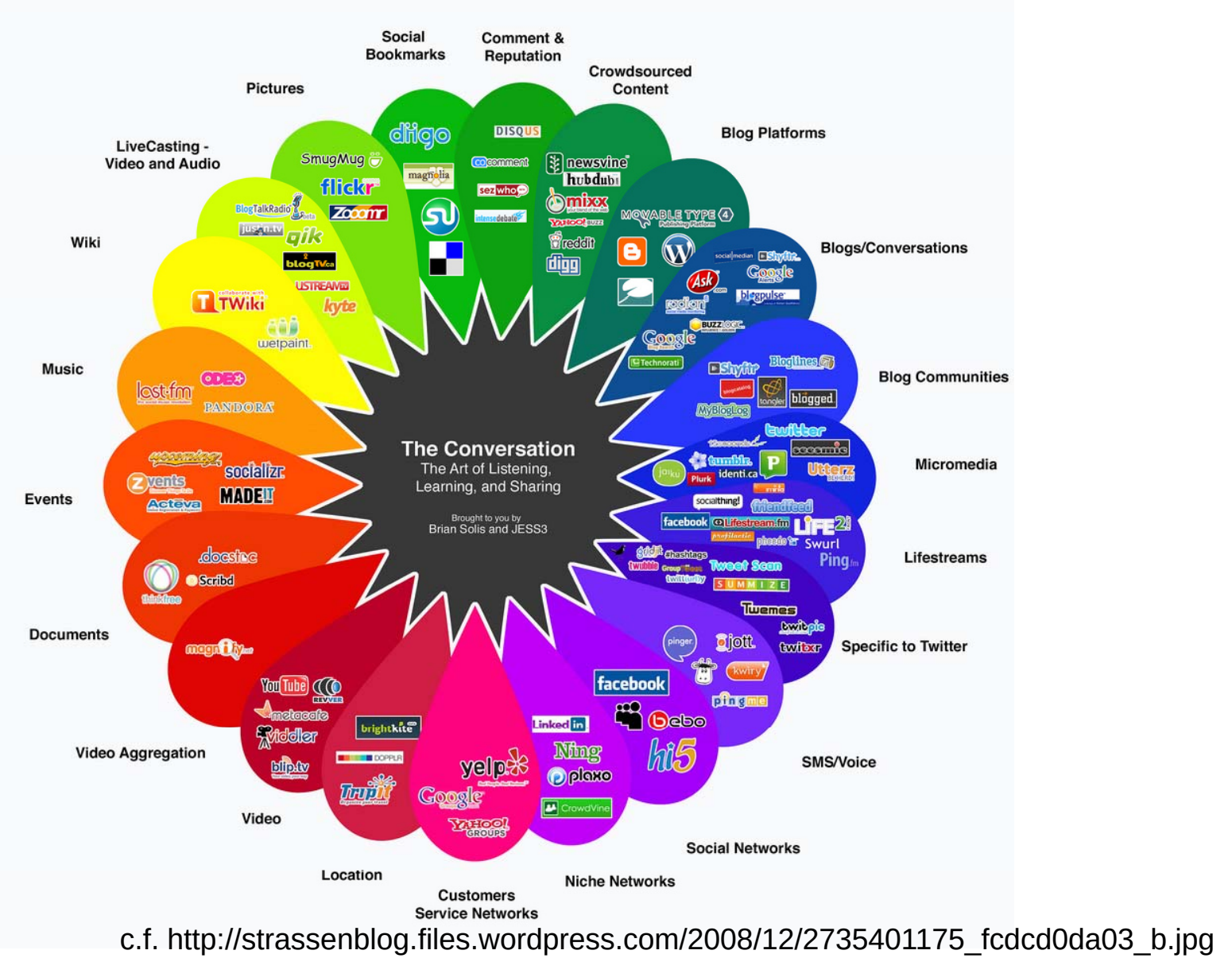
⇨ having Internet with right properties has enormous beneficial impact

Society needs Sustainable Networks

- *Needs [by David Hutchison et al.]*
  "The Future Internet" needs to be able to *sustain networks* on all levels, from low level links up to overlay networks and transient collaboration and resource sharing across applications. In the ever-changing dynamic world, the network must maintain stable services while resources, demands, relationships and the network itself change over time. Since changes on one level affect other levels, a holistic and multi-disciplinary approach to sustaining the network is necessary. The roles of network users – and other key influences – must be taken into account alongside purely technical issues."
- *Internet Science allows us to engineer sustainable networks*
  - predictable service properties and evolvability
  - resilience to any challenge
  - content-centric-ness
  - network efficiency
  - trustability



Impact on Society



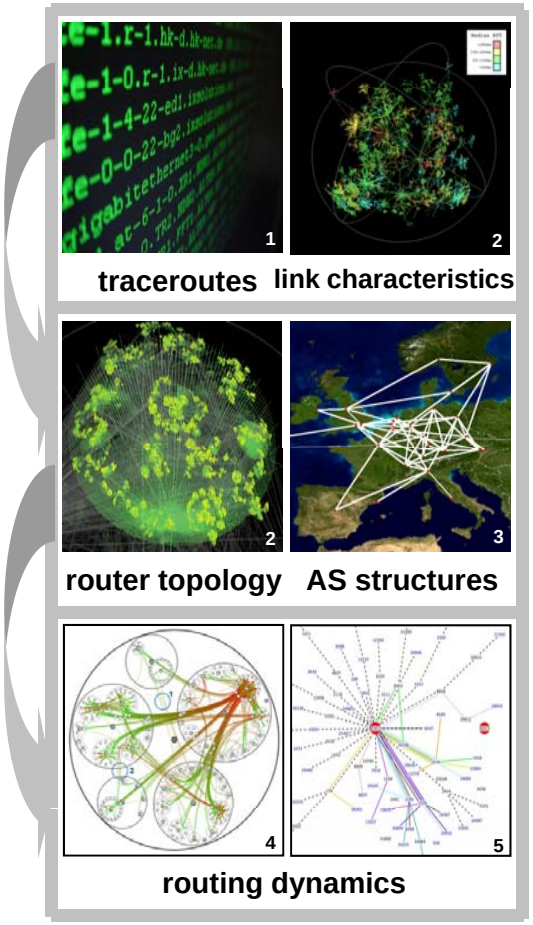
c.f. http://strassenblog.files.wordpress.com/2008/12/2735401175_fcdcd0da03_b.jpg

Integration: Inter-disciplinary Approach

- Disciplines: This research needs to bring together scientists from
  - computer science :computer systems, software engineering, information systems, theoretical computer science
  - Mathematics and system theory
  - Physics and complex systems analysis
  - Economics to understand social/economical interactions
  - Psychology and sociology
  - Information theory, signal processing and communication
  - and from the application domains served by the Internet, such as energy and live sciences.
- Methods: The research needs to combine
  - theoretical activities
  - empirical approaches and realistic experiments

On Integration: Analysis and Design Approaches

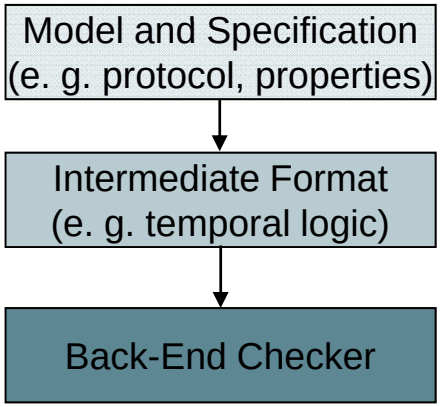
- Analysis of the Internet structure

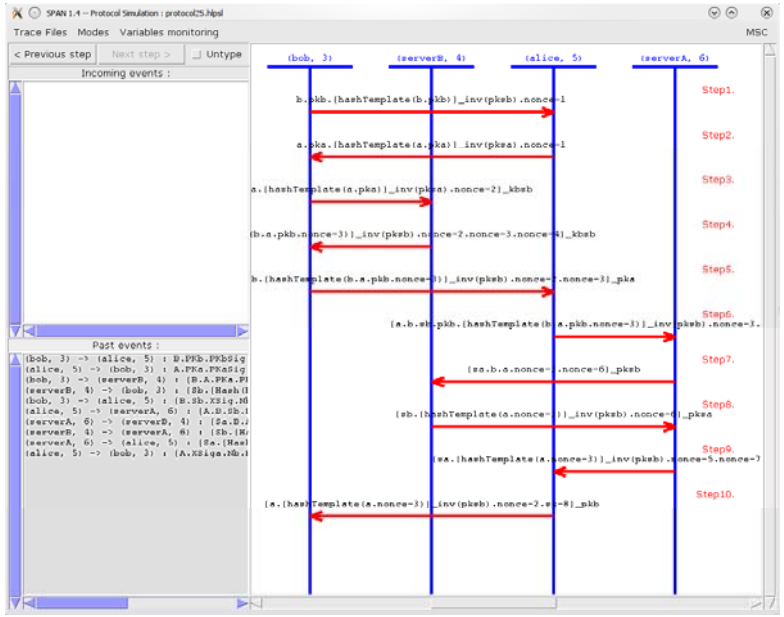


Pictures from:

[1] http://www.cqsys.com/
[2] http://www.caida.org/
[3] http://www.cs.washington.edu/research/networking/rocketfuel/
[4] http://www.win.tue.nl/~dholten/
[5] http://www.bgplay.uoregon.edu/bgplay/

- System engineering and validation, using temporal logic, model checking, …





Plausibility: European Constituency as Key Player

- Compelling research program can be put together
- Making use of combined skills of a range of communities with stake in a Future Internet to form a science for Global Information Infrastructure
- R&D programs with large-scale, long-term multidisciplinary activities and visionary research
- Encourage and support research collaboration with science leaders worldwide
- Builds on ongoing activities of the rethinking the Internet architecture
  - EU FP7 Challenge 1: Pervasive and Trusted Network and Service Infrastructures: Objectives 1.1 Network of the Future
    + Objective 1.6 New Paradigms and Experimental Facilities (FIRE)
  - Future Internet Assembly (FIA)
  - US National Science Foundation: Future Internet Design (FIND)
    + Network Science and Engineering (NetSE)
- Recommendation
  - constituent communities within EC should work closely with global programs aiming at the Future Internet, particularly with NSF.
  - a significant effort is needed that European stakeholders are equal partners, and key players in the Future Internet endeavor
    ⇨Europe cannot afford that the USA leads uniquely in this space.

Expected Support: Future Internet Community

- Builds on findings of Dagstuhl Perspectives Workshop: "Architecture and Design of the Future Internet", 14 – 17 April 2009, Organizers: Georg Carle (TUM), David Hutchison (Lancaster Univ.), Bernhard Plattner (ETHZ), James Sterbenz (Univ. of Kansas)

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- Many key persons from Future Internet research and adjacent disciplines
- Level of progress since initiation of the Internet Science Initiative
  - Numerous expressions of interest have been received to join the FET Flagship Internet Science initiative
  - Input integrated on need of sustainable network properties, and of impact on society