Future Internet(working) architectures

Raimo Vuopionperä (Ph.D.)
Research Manager, NomadicLab
Ericsson Research (@ Finland)

E-mail: Raimo.Vuopionpera@ericsson.com, phone: 09-2992160

Outline

- Acknowledgements
- Background/History
- Grand Vision
- Problems – a closer look
- Future Challenges
- Research Directions (FI Architectures)
  - One example – deeper look (if time allows)
- Summary
- EXTRA: ICT SHOK Future Internet – ”A Finnish Initiative” (if time allows)

Acknowledgements

- The material for this presentation is borrowed (with their permission) from:
  - Pekka Nikander (Ericsson)
  - Hannu Flinck (NSN)
  - Henrik Abramowicz (Ericsson)
  - Christian Vogt (Ericsson)
  - Petri Jokela (Ericsson)
  - and from others who participated to the preparations of ICT SHOK “Future Internet” Strategic Research Agenda/Area (SRA)
    - E.g. Martti Mäntylä (HIIT), Pasi Särolahti (NRC), Jouni Korhonen (TeliaSonera) + many others.

”Clarification”/”Disclaimer”

Please do not confuse ”INTERNET” with the ”WEB (ver. ?)”,

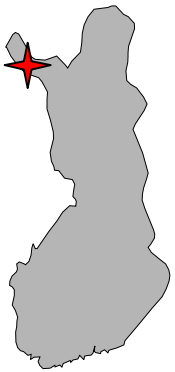
since I am going to talk about the (Future) Internetworking

NOT

about the Future of the Web (wheter it be 2.0, 3.0, ...) or Services evolution etc.

My CV

Karesuvanto →



Younger me →

Education

- Enontekiön lukio 1986
- M.Sc. in Theoretical Physics, Univ. of Helsinki 1992
- Ph.D. in Theoretical Particle Physics, Univ of Hel. 1996

Other

- **Born (1.4.1967) in Finnish Lapland**
  - Mother Norwegian, Father Finnish

Misc. (e.g. hobbies, etc.)

- Reading SciFi & Fantasy!
- Following Motorsports (especially DragRacing :-)
- Cooking (somewhat)
- Family (2 kids)

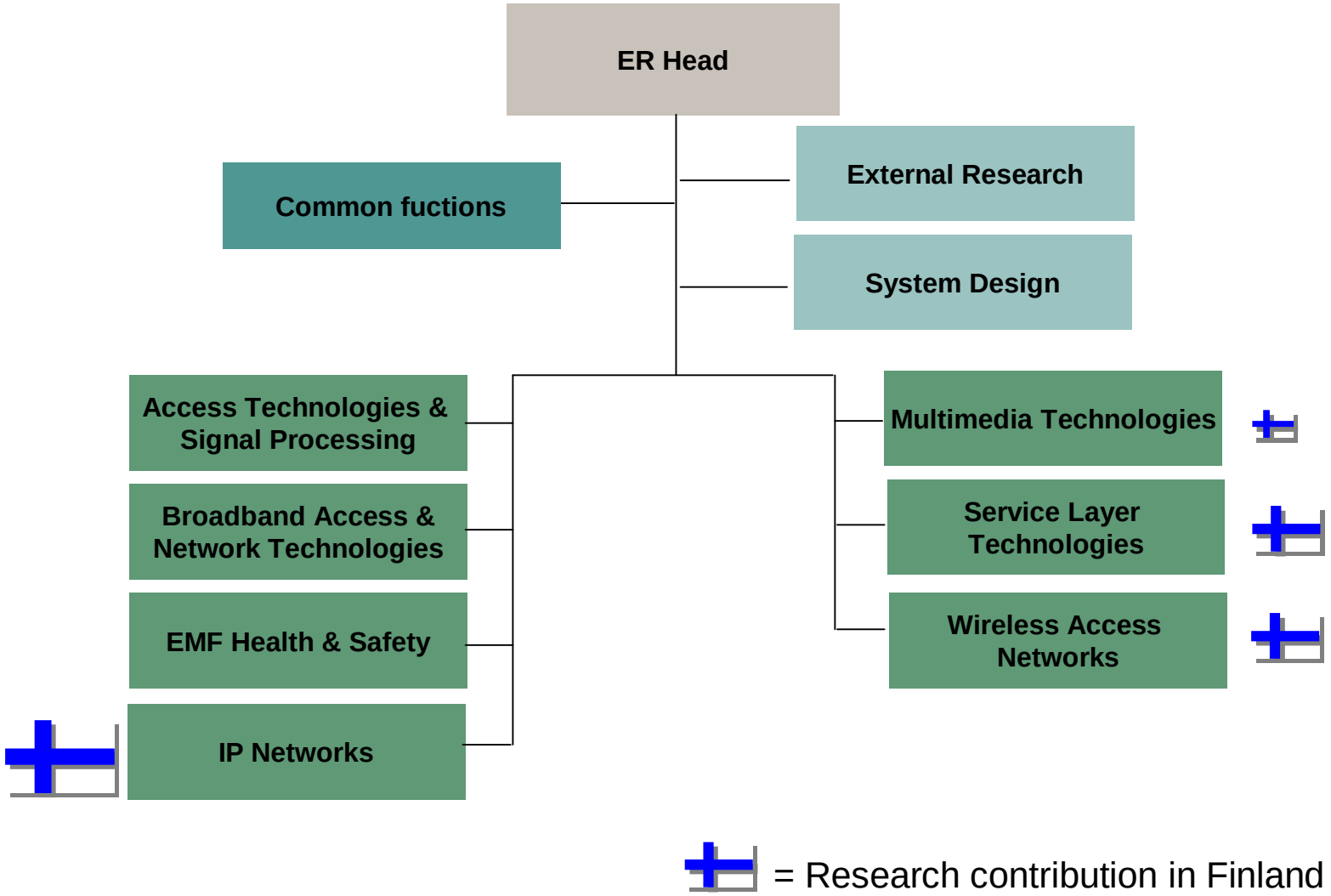
Career

- 1989, Research trainee
  - Worked 1 month at CERN (Geneva)
- 1990 Worked 4 months at CERN (Geneva).
- 1991 Military Service (Vänrikki)
- 1992 Worked 2 months at CERN
- 1994 Worked 6 Months at DESY (Hamburg).
  - Otherwise (e.g. while studying) I worked as research assistant at department of Physics at the University of Helsinki.
  - Have also appeared (interviewed at science programs) @ National Radio and TV programs.
- Summer 1996 – Dec 1997, worked as Post doc. At CERN.
  - Lived actually in France (St. Genis P.).
- 1st of March 1998 joined Ericsson as a “Internet Researcher”.
- Fall 1998 section manager at NomadicLab.
- May 1st 1999 -> NomadicLab Research Manager.

NomadicLab

- Ericsson Research (IP Networks, Wireless Access Networks and Service Layer Technologies) Representative @ E/// Finland!
  - Belongs to Oy L M Ericsson Ab (LMF) Telecom R&D organization.
  - HEADCOUNT: 47 researchers working on various projects.
- Presently 5 main research areas:
  - (IP) Networking Architecture
  - (IP) Networking Security
  - (IP) Multimedia

Ericsson Research



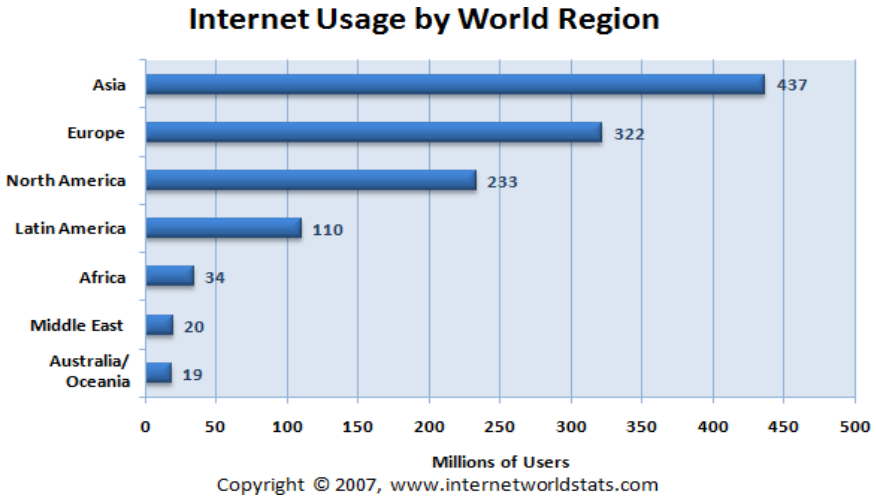
NomadicLab…

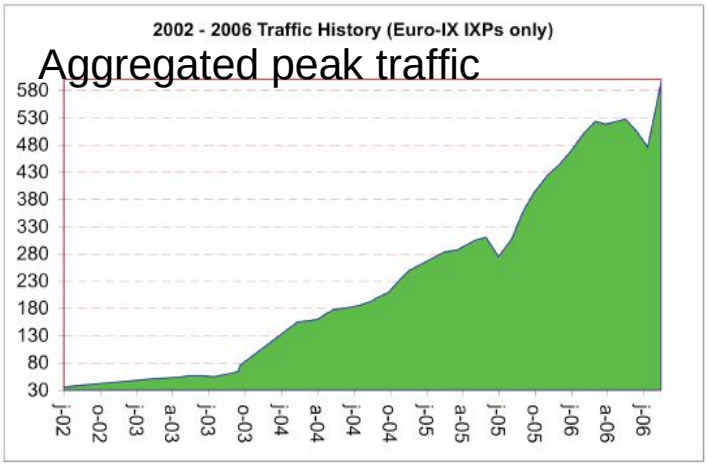
- Big Part of our research results are contributed to standardization forums or are published either in conferences or scientific journals!
  - In addition to that we are actively participating to prototyping effort that aim at introducing the new features to wireless systems.
  - BUT … We also patent our ideas [>>1 patent/person/year]
- Active participation both to Nation wide (e.g. with Universities & Local companies) and to EU wide research collaboration projects.
  - We are also cooperating directly with external companies/universities!
  - Some visiting external researcher have worked at NomadicLab (Possibility also in the future ☺)
- Participation to international standardization forums (mainly IETF and 3GPP) is also one of the main goals of the Nomadiclab operations.
  - ~>70 RFC's (inc. RFC Queue; ~< 50% Finnish RFC¨s).
  - Leading positions (i.e. many IETF/IRTF WG Chairs) at the IETF, including (only 2006 main achievements listed)
    - Jari Arkko nominated to Internet Area Director (@ IESG).
    - Gonzalo Camarillo nominated 3GPP liasion for IETF.

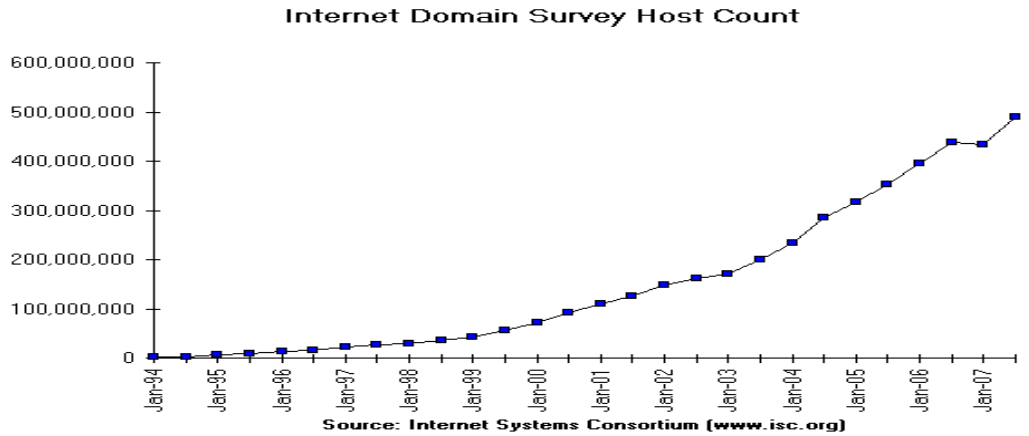
Background/History

The Success of Internet also its failure?

Tremendous success

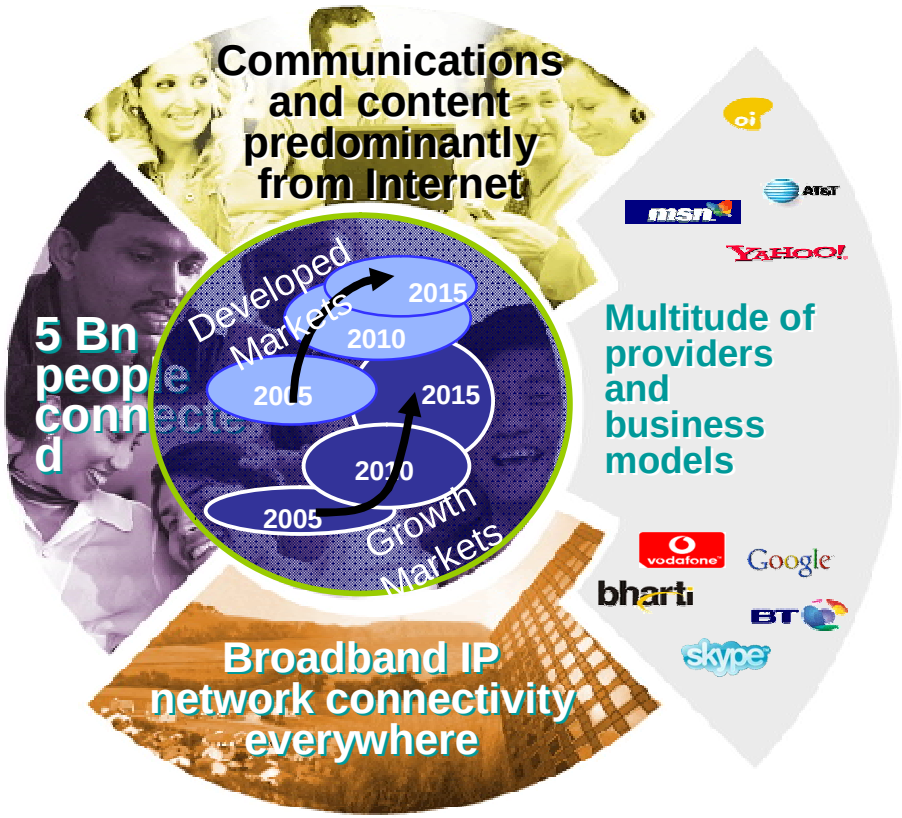






Source: European Internet Exchange Association 2006 Report on European IXPs

Impacts all communication and content businesses



New services driven by Internet

- Global reach with 1 billion potential users
- Superior value for consumers and businesses
- World wide innovation community

New business models driven by Internet

1. Obtain big subscriber base with “free” service
2. Monetize with different business models

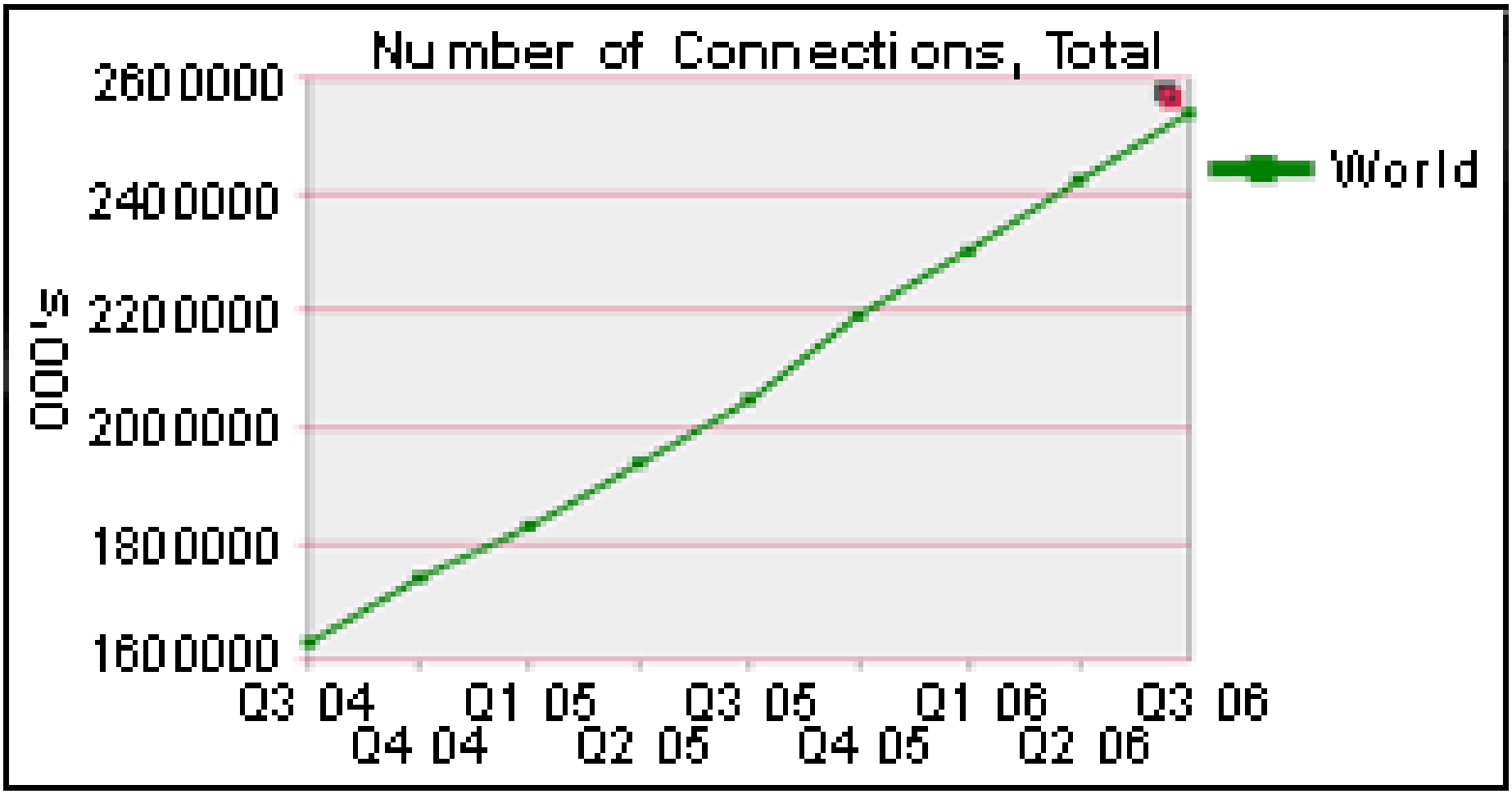
Broadband usage driven by Internet

- Services independent from access
- Exponential demand for network capacity
- Significant growth in network connectivity

Tremendous success, so where is the problem?

- Internet has grown out of its original design scope (Originally defined by US Military)
- The original design assumptions do not meet the current realities. Some examples:
  - End users are not as the used to be:
    - Mutual trusting and co-operating community challenged by selfish behavior: security threats, SPAM, malware, unsolicited ads
    - Retrieval and unicast communication evolving into social networking
  - Hosts are not as they used to:
    - Desk top hosts vs. multi-interface and mobile hosts
  - Huge variability of link layer characteristics:
    - from WLAN to satellite and 10s of G/bits Ethernet
  - End to end design principle vs. firewalls, NATs

Mobile growth



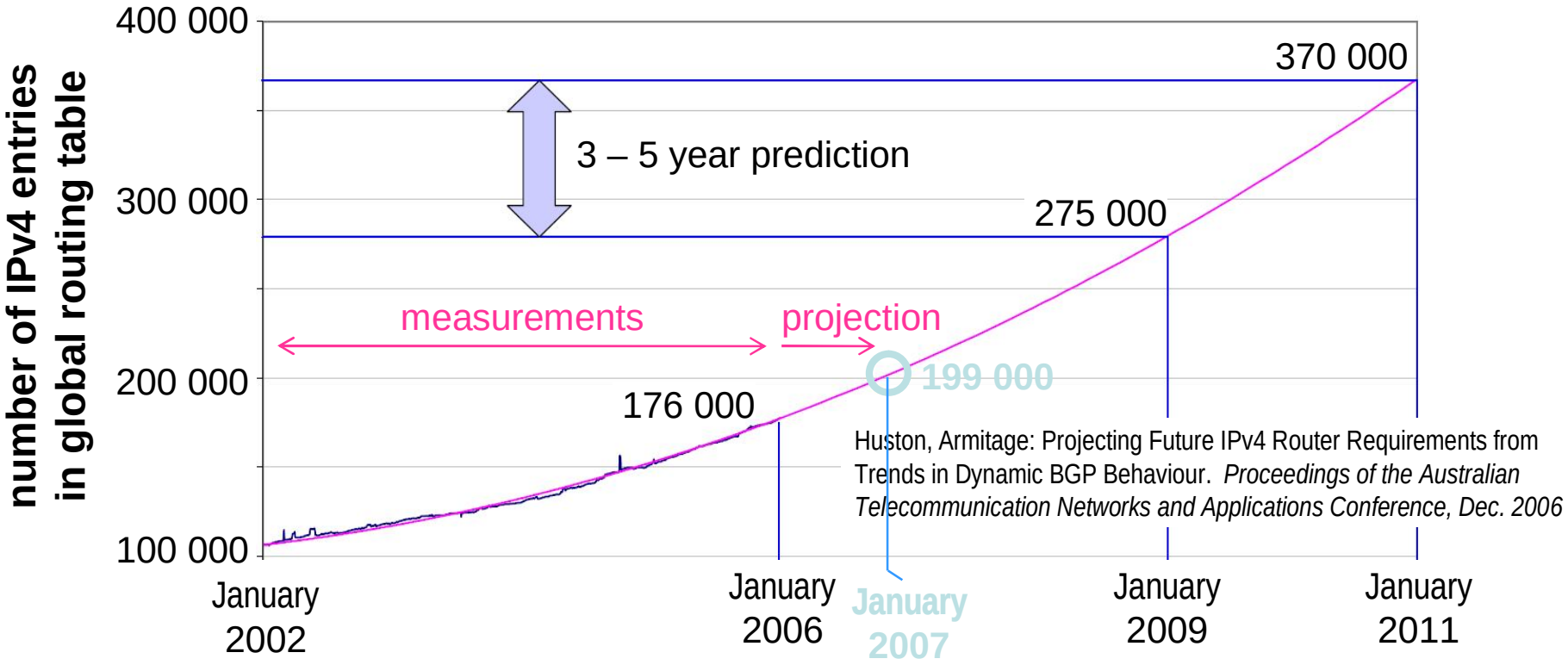
Source GSMA

GSM/UMTS 2.4 bill 1Q 07

Tremendous success, so where is the problem? (cont.)

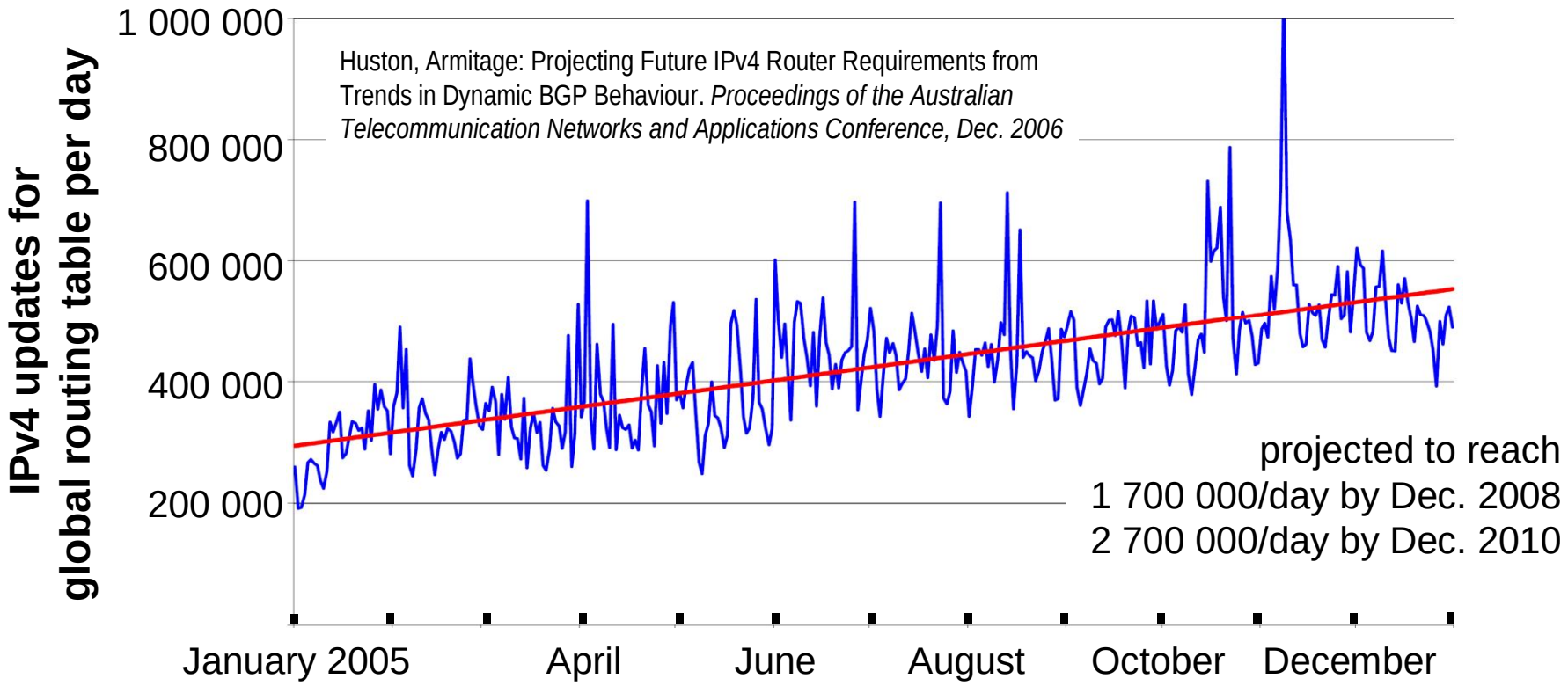
- Popularity of the overlay network applications is a testimony of missing functionality
- Cost of success => scalability problems
  - Routing table growth
    - More expensive core routers (CAPEX)
  - Address space exhausting
    - More middleboxes and management (OPEX)
    - Complexity into to application design to detect the middleboxes (slower innovation, looming stagnation)
  - DNS overloading
    - Used for service discovery, public key distribution, etc
    - Additional dependency in service deployments

Evidence of Scalability Problem



- Measurements indicate faster-than-linear growth
  - Internet growth combined with increased multi-homing and traffic engineering
  - Predictions for early 2007 were met
- Further growth potential
  - Large IPv6 addressing space
  - Spot market expected to fragmentize IPv4 addressing space

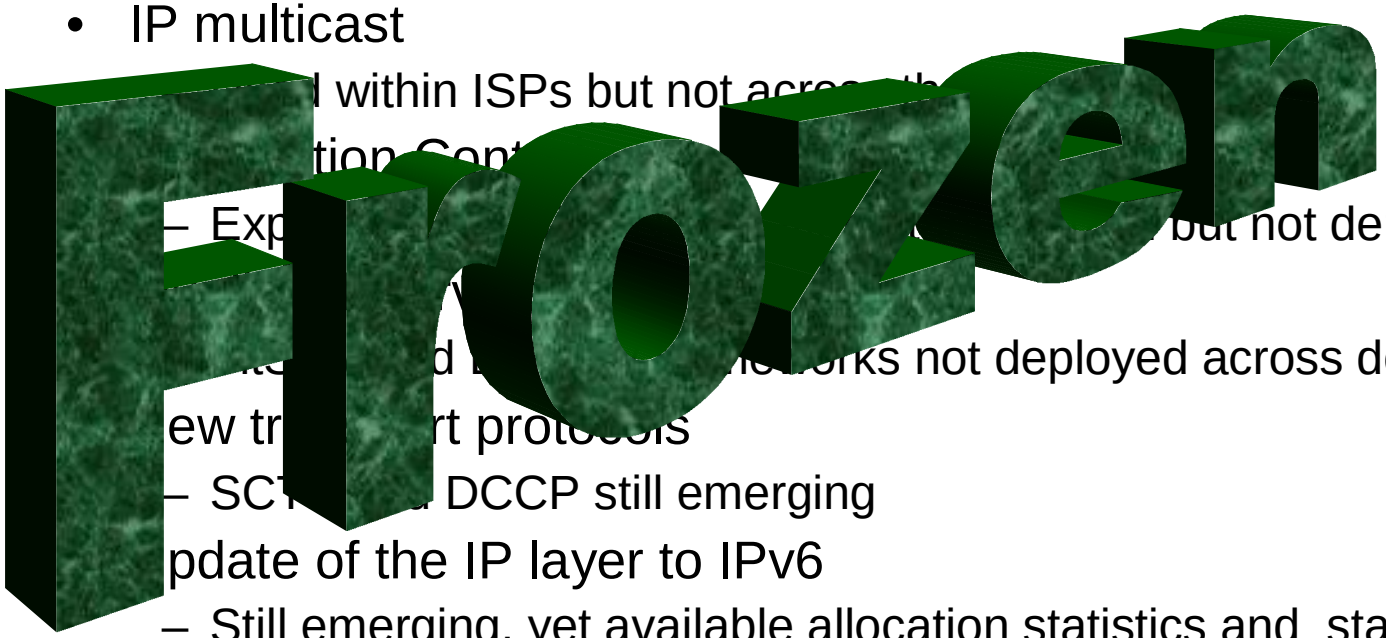
Evidence of Scalability Problem (cont'd)



- More frequent router upgrades or replacements expected
  - Memory upgrades to fit growing routing table
  - Processor upgrades to accommodate update frequency growth
- More scalability desired

Problem amplified: Outdated IP layer

- Previous attempts to update the Internet
  - IP multicast
    - within ISPs but not acro
    - tion Cont
    - Exp but not deployed
    - networks not deployed across domains
    - ew tr rt protocols
    - SCT DCCP still emerging
    - pdate of the IP layer to IPv6
    - Still emerging, yet available allocation statistics and statistical analysis of the data indicate that the available IPv4 address pool (at IANA and RIRs level) will run out in 3 years. Btw
- IPSec, BGP-4 made their way to the core



What went wrong with these core protocol updates?

- Did they solve a real problem
  - **YES, Absolutely**
  - Can their deployment be justified in commercial terms?
    - **Yes**, they have all reasonable use cases and tangible benefits for (wrong) parts of the value chain
  - **Observation**: those technologies get deployed in the core of the Internet that solve an immediate fatal problem (like BGP-4) or when they offer clear monetary advantage (like IPsec)
  - **Conclusion**: technologies that benefit the community at large but do not offer immediate return of investment to the party who deploys will only cause extra expenses (inverse of the Reed's). Any actor in the value chain can stop or delay the deployment.
- AND it will get worse in the future, ref. M2M.

Mobile control communication areas – M2M

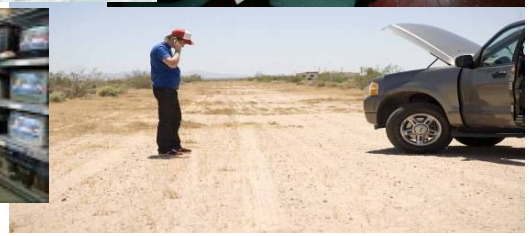
Home and office
- Remote control of consumer electronics and appliances
- Monitoring
- Security, door access

Fun and leisure
- Pervasive gaming
- Tourism guidance

Convenience
- Lost and found items
- Home control
- Shopping
- Location services

Logistics
- Cargo tracking
- Route planning
- Stock management

Sales and payment
- Vending machines
- POS terminals
- Advertisements



Industrial
- Service & maintenance
- Process automation
- Agricultural & forestry
- Environmental

Health, Safety&Security
- Health monitoring
- Property monitoring
- Environmental and weather monitoring

Telematics/in-vehicle
- Navigation
- Safety
- Vehicle diagnostics
- Traffic information

➔(More) Key Drivers

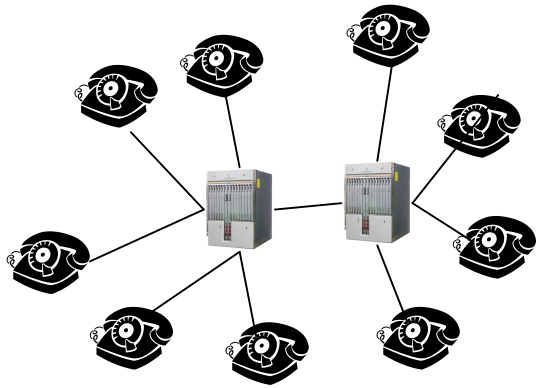
- Mobile phones become multimedia computers needing high bandwidth access to content
- Web 2.0 applications need of always available connectivity to network embedded storage and applications
- Sensor applications broaden the scope of the Internet into physical world
- Voice and data convergence sets new levels for capacity, performance and usability requirements
- New business models are emerging that build on the access independency, global reach, huge existing content, application and developer base of the Internet

Grand Vision

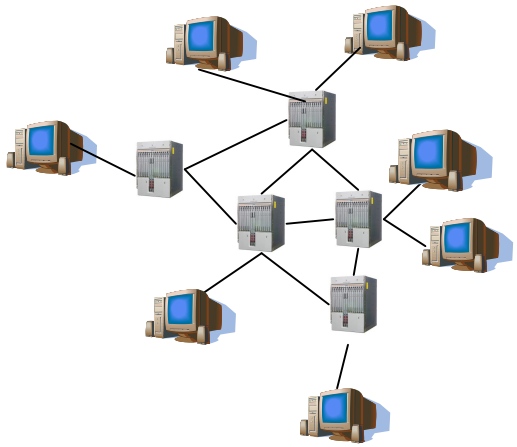
Grand Vision: Networking of Information

(R)Evolution

Telephony
Interconnecting *wires*



Internet
Interconnecting *hosts*



Future Internet
All-communicating world
Interconnecting *information*

- Interconnecting a World of Information Objects
- Inherent support for Security, QoS, Mobility, Self-Management
- Multi-Business Connectivity

Three waves of networking

1930

1960

2020

First wave: Wires

- Connect wires
  - Technically: line interfaces to other line interfaces
- Value creation: wires to every home and office
- Encouraged monopolies

Second wave: Nodes

- Connect users to multiuser hosts
  - Remote access
- Slew of issues, e.g.
  - IP connectivity model
  - Suitability of TCP
- Encouraged distributed operations

Change of the paradigm

- Intended Killer app of 1980s: Remote access
- Focus on end-points (mainframes/minicomputers)
- Used existing wires, but differently than before
- Un-intended Killer app of 1990's: E-mail, WWW
- Adaptive routing increased reliability exponentially as the number of routers and links grew
  - But then we hit the limits of scalability and business
- No call set up -> high efficiency

Third wave: Information

- Advertised heavily by Van Jacobsen of PARC
  - Build on top of the Internet, like the Internet was built on the top of wires
- Eventually to replace Internet like Internet is now replacing phones…

Problems

A closer look

Present problems

SRA defines future challenges

- **Information networking**
  - New concepts of naming, addressing and routing to optimize the access to information
- **Changing usage patterns**
  - Create, search and share information
  - Maintenance of social networks
- **Network Socio-economics**
  - Rules to encourage appropriate behaviour

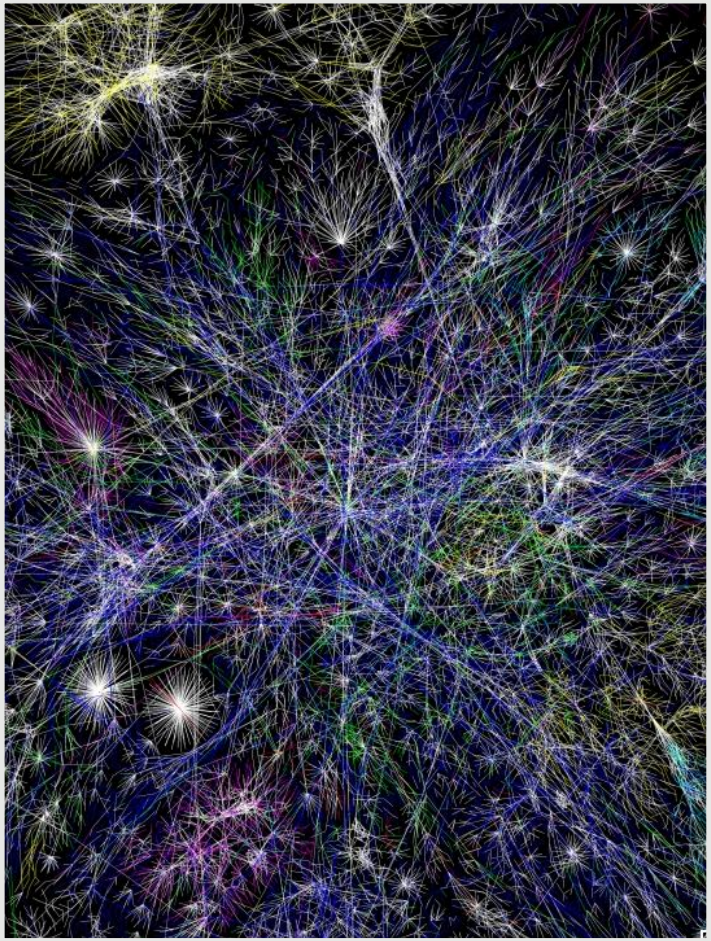
- **Autonomy and Resilience**
  - Configuration agility
  - Self healing, self management
- **Energy Consumption**
  - Adaptation of the whole stack from the energy constrained network discovery and routing to higher levels
- **Shifting Bottlenecks**
  - Allocation of work between processing, storage and communication

Unwanted traffic

- Spam, DDoS, Phishing,
- Root cause in economics
  - Cost of sending lower than cost of receiving
- Security:
  - Internet was initially designed with a cooperative environment in mind
- The prime example of current, negative externalities
  - An emergent property

Scalability of routing

- Traffic engineering, Routing based multi-homing, BGP rigidness
- Success of the Internet, Business environment
- IPv6 likely to make worse, not to remedy
- NAT traversal
- Experts disagree on the severity of the problem



Mobility and multi-homing

- Missing indirection
  - IP address has a dual role of node identifier and network locator
  - Point solutions
- HIP: comprehensive, architectural attempt
- Other entities but nodes

Picture Copyright © 2005 Antoine Valentim

Resources and compensation

- Long and short term shortage – moving target
- Resolve congestion through compensation (market arbitration)
- Structure compensation to encourage capacity growth

Trust and reputation

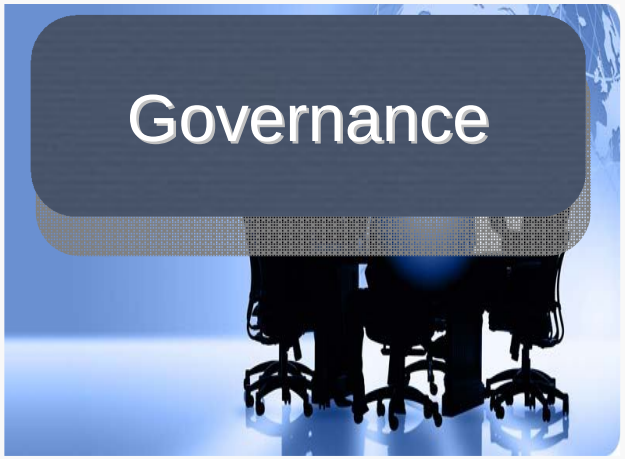
- Original Internet design assumed trusted environment
- Today we secure the channel between source and sink
- But – unclear if source and sink are trustworthy?
- We can’t build a secure system – need to build on social infrastructures

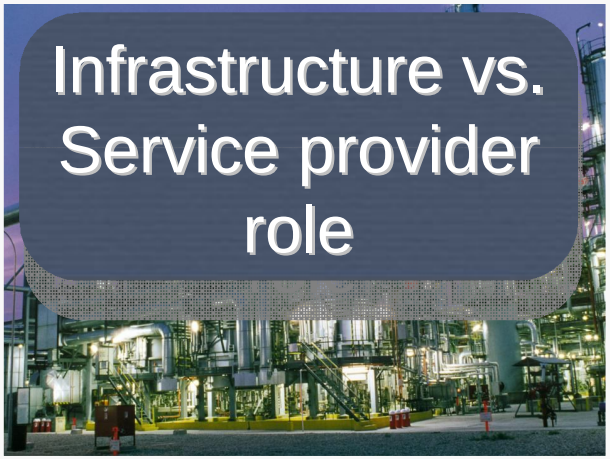
Privacy and attribution

- Transparent society unattainable
- Need to drive privacy to a basic characteristic of the network
  - Balanced with accountability

Other Fundamental problems in present Internet

Other fundamental problems in present Internet





Governance

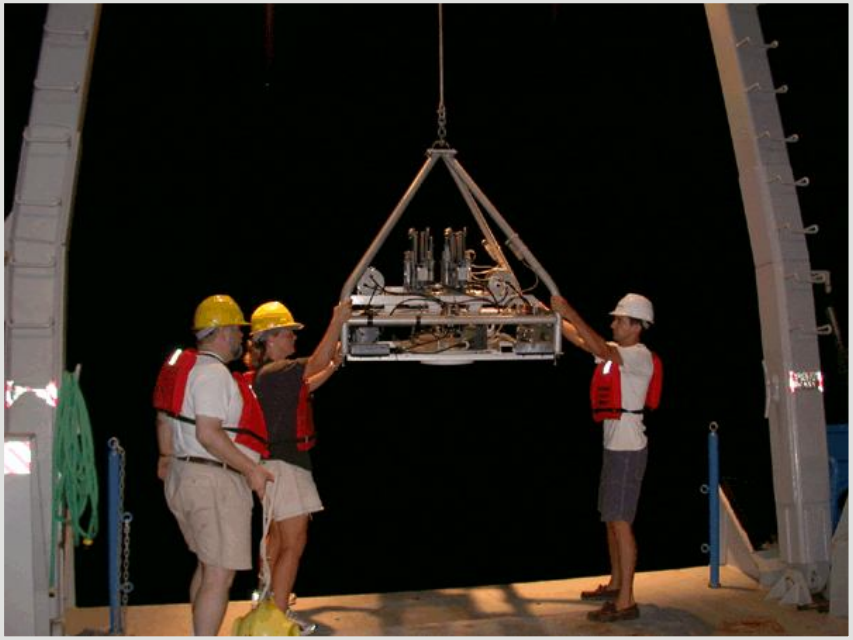
- US vs. the rest of the World
- IPv4 addresses are running out (really this time)
- IETF vs. ITU-T
- ITU-R (Communications vs. TV industries)

Infrastructure vs. Service provider role

- Operators want:
  - Customers that pay high prices for ‘sophisticated services’ using few bits
- Customers want:
  - Big cheap bit pipes
  - Fun & Free services

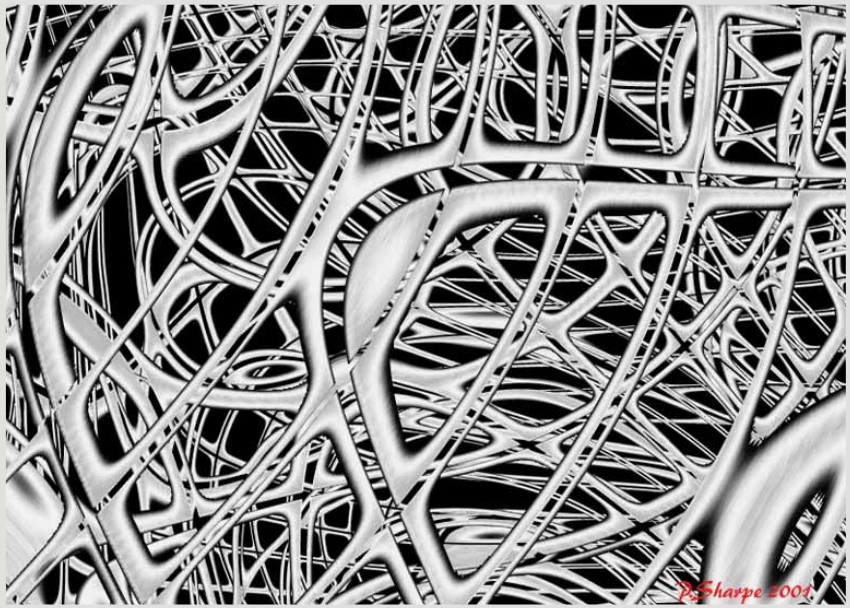
Deployment problems

- IPv6
- QoS
- Mobility
- Security
- Combining them ALL?



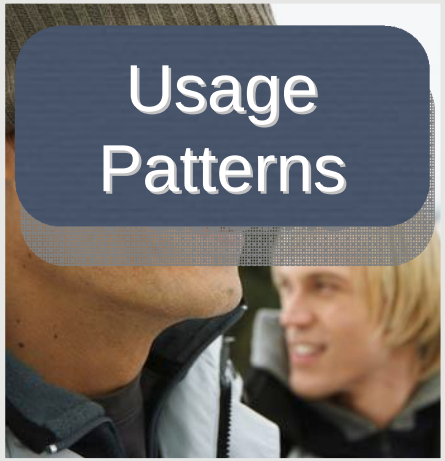
Configuration & Management complexity

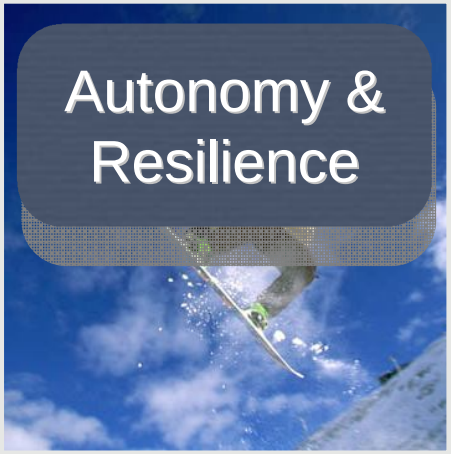
- Opex dominating cost
- Most serious network problems due to configuration mistakes
- Middle boxes, firewalls



Future Challenges

Future challenges



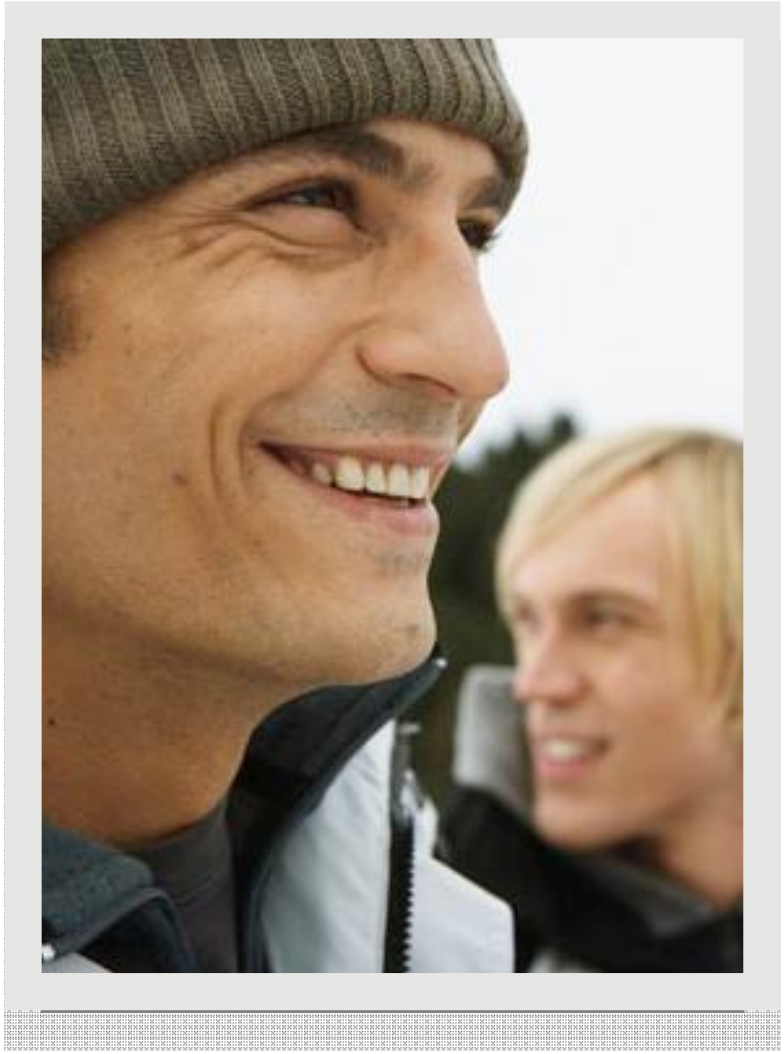


Information networking

- The third wave of inter-networking
- Rethinking of the architecture
  - Naming, addressing, routing, caching, …
  - New elements
- Old problems in new disguises

Changing usage patterns

- Complex interactions between behaviour and social structures
- Infrastructure, configur-ability, and practices
- Unpredictable new traffic patterns
- New types of risks & business models



Network socio-economics

- Driven by diminishing transaction costs
- Continuing power battles
- New emerging business opportunities
  - Threats?

Autonomy and resilience

- Configuration agility
  - Zero configuration
  - Auto-management
- Self-optimization
- Organic resilience
  - Ideas from CAS

Energy consumption

- Biggest problem in today's data centers
- Batteries likely to remain a problem
- Cross-layer interactions
- Rethinking radio and inter-networking

Shifting bottlenecks

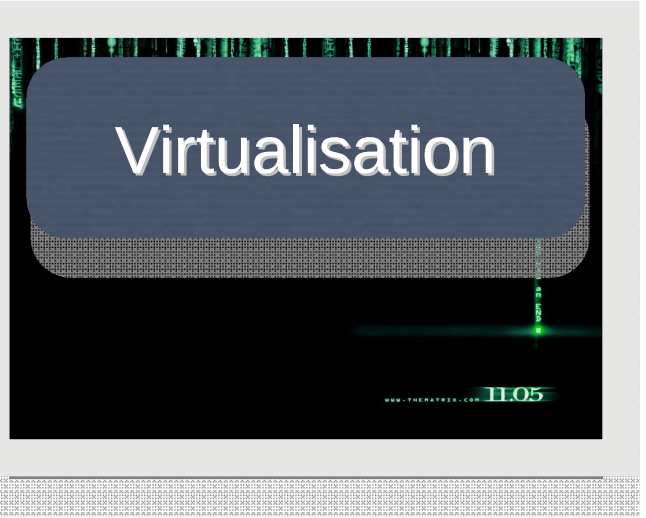
- Managing flexibility
- Speed of light will remain a problem
  - Consequences: e.g. caching and cache consistency

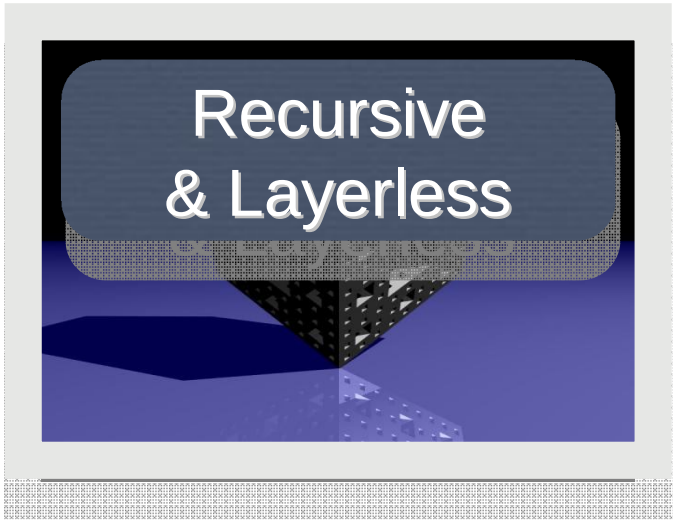
Research Directions

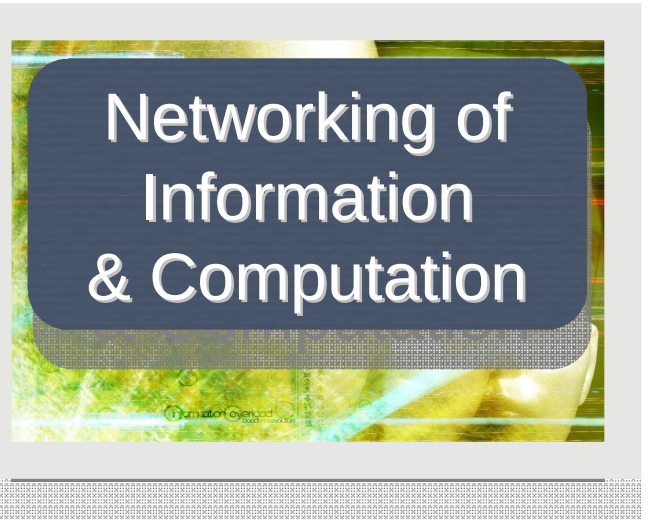
Read:

Future Internet Architectures

Research Directions





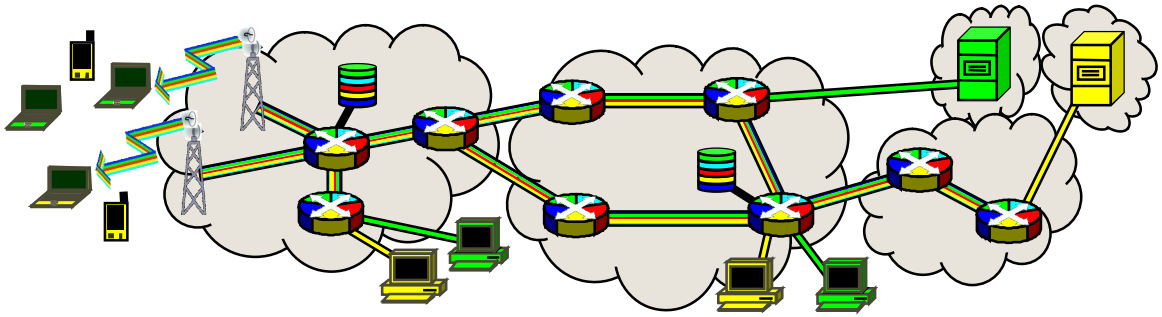


- Medium term: Middle and Overlays
- Long term: Virtualisation, recursive and layerless, Networking of information

Middle boxes and overlays

- Main line of research today
- Unlikely to resolve any of the major problems
  - Alleviation possible, of course

Virtualisation



Parallel virtual networks

- Multiple network stacks
  - Easy to install new stacks
- Independent evolution
- Allow contradictory requirements
- Single infrastructure
- Interworking???
- Management of shared resources

Virtualisation vs. the problems

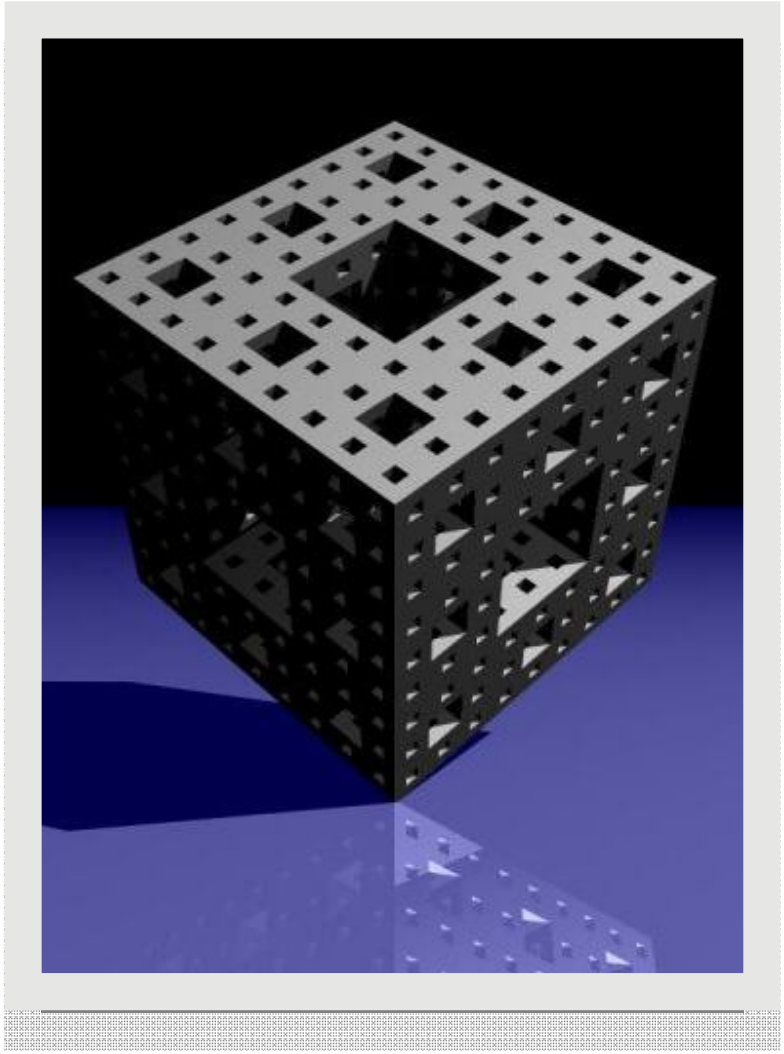
- Unwanted traffic: May help through isolation
- Resources and compensation
  - Provides a new level of granularity; reduces flexibility of resources
- Trust and reputation
  - Isolation may help; Parallel networks may create new problems
- Privacy and attribution: No direct relationship

Virtualisation projects

- VINI — Virtual Network Infrastructure
- CABO — Concurrent Architectures are Better Than One
- Diversified Internet — an architecture for
- 4WARD
- GENI

Recursive and Layerless

- One layer with plug-able and tuneable mechanisms
- … or mechanisms / managers that can be plugged together
  - State management, End-to-end congestion control, Switching / forwarding



Layerless & Recursive vs. the problems

- Do not directly affect unwanted traffic, compensation issues, trust and reputation, privacy and attribution
- Adds flexibility, providing
  - better, more optimised services
  - faster evolution of the architecture
- May create completely new security problems
  - e.g. unwanted layer interactions

Recursive and layerless projects

- Layerless
  - Haggle
    - EU FET project
    - Quite large, lots of people involved (about 25)
  - SILO — Service Integration, controL and Optimisation
- Recursive
  - RNA — Recursive Network Architectures
  - 4WARD Stratum concept

Networking of Information

- The major trend…
- Data as first class object
  - Self-certifying data
- Layer “above” inter-networking –
  New internetworking
- Tolerating intermittent connectivity

Fundamental changes

- Hosts are no more important
- May integrate the storage system and the network
- TCP becomes very sub-optimal
  - Not good for real-time person-to-person traffic
  - Not good for non-real-time, cacheable objects
- Routing and addressing needs to be rethought

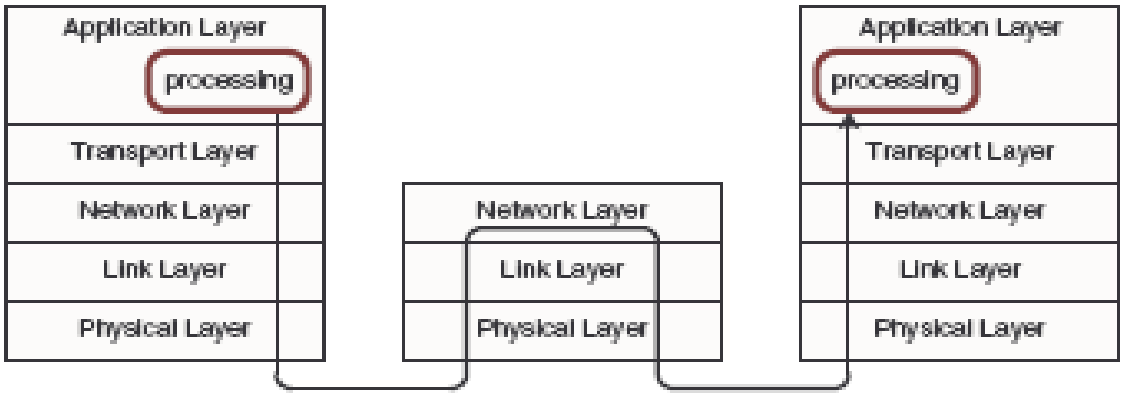
Relationship to the present problems

- Unwanted traffic
  - Some forms impossible; changes dynamics
- Resources and compensation
  - More important; mandates creation of markets
- Trust and reputation
  - Focus shifts from nodes to information and actors
- Privacy and attribution
  - Changes nature completely, but still a problem
- Mobility & Multihoming
  - Simplified through ID/Locator split

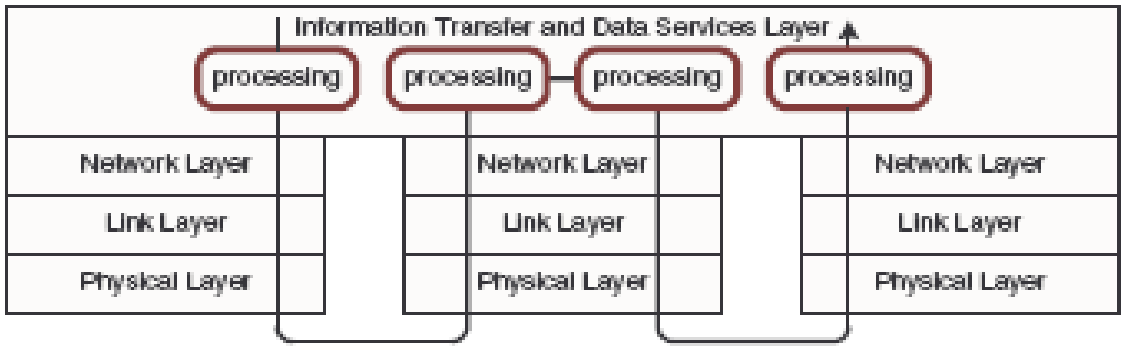
Existing and planned projects

- Content centric networking (Van Jacobsen's)
- Postcards from the Edge
- Data Oriented Network Architecture (DONA)
- Service Centric End-to-End Abstractions
- 4WARD Networking of Information concept
- Publish-Subscribe Internet Routing Paradigm (PSIRP)

Service-Centric End-to-End Abstractions



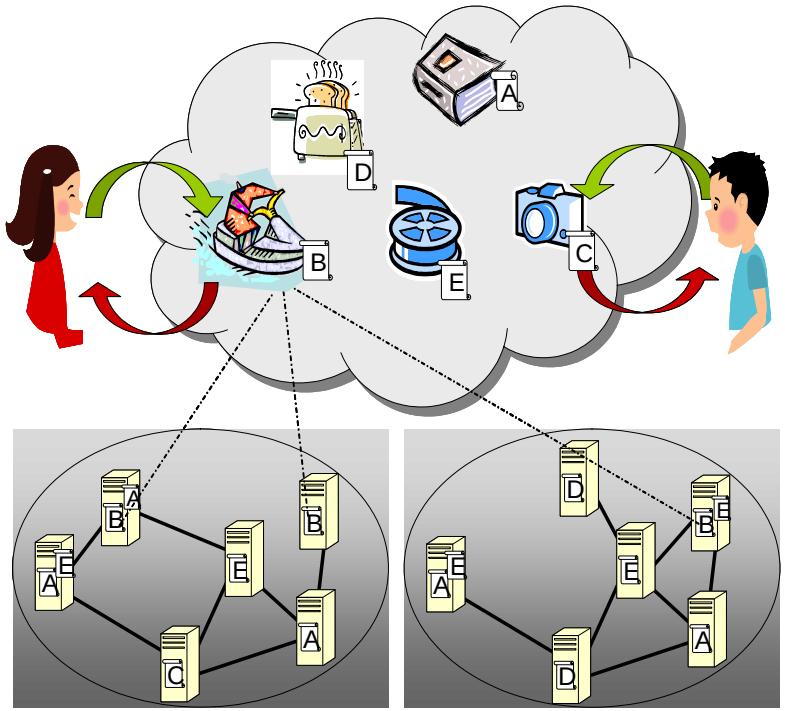
(a) Layered Internet Architecture



(b) Information Transfer and Data Services Architecture

4WARD
Networking of Information

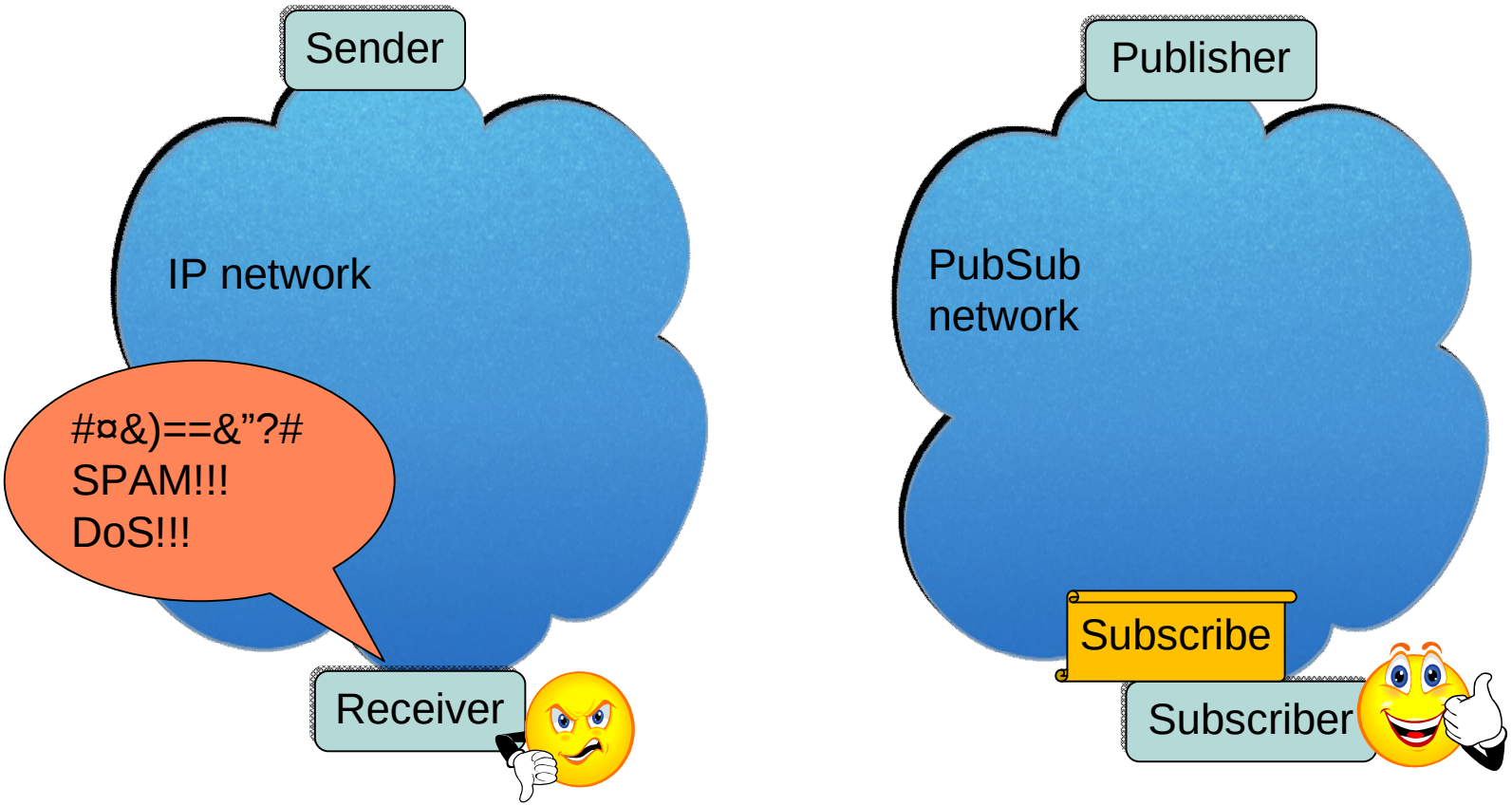
- NetInf Architecture
- Information modelling
- Basic dissemination mechanisms and services
- Non-dissemination and delay-sensitive services
- NetInf evaluation



PSIRP: Publish—Subscribe

- Information handles replace IP addresses
  - Identifies a piece of published information
  - No more possible to identify the destination
- Multicast as a basic primitive
  - Multiple subscribers
- Both sender and recipient needed
  - Impossible to send completely unwanted traffic
- Tuple spaces replaces message passing

IP vs. PubSub Internetworking



Basic technical idea

- Publish–subscribe based internetworking
  - Forget IP, send( ), receive( ), routers, TCP handshake
- Rethink everything, i.e., the whole paradigm
  - Forget Message Passing based IPC
  - Welcome Black board / tuple space based IPC
- Manage data delivery
  - Rendezvous: rendezvous near sender, not receiver
  - Routing: build a (sub-optimal) route
  - Forwarding: efficient data delivery

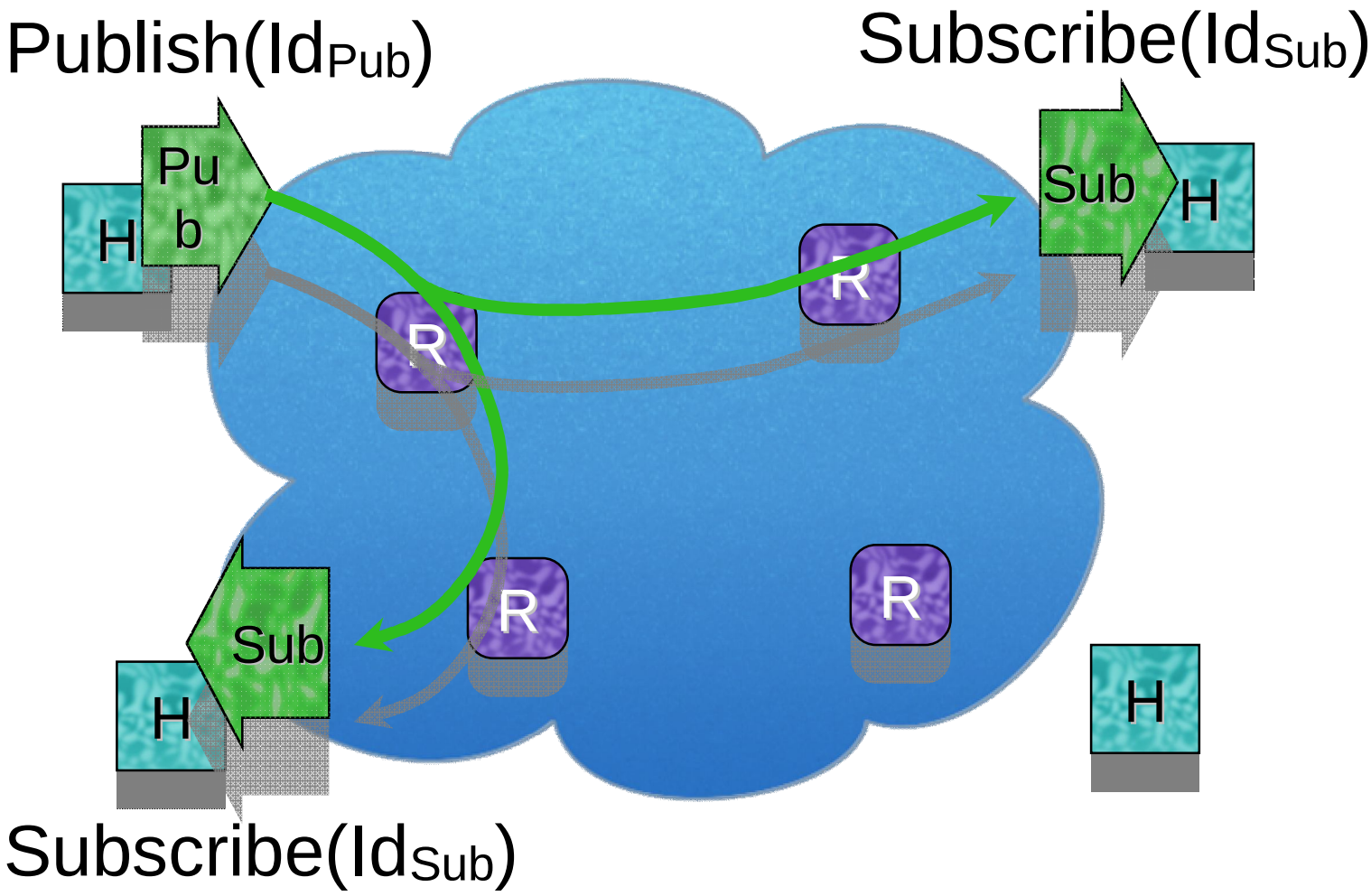
Basic technical idea

- Publish–subscribe based internetworking
  - Forget Internet Protocol packet formats
  - Forget send() and receive() socket calls
    - and everything based on them, i.e., the whole API
  - Forget routers and forwarding as we know them
  - Forget TCP three-way handshake
  - Forget network management as we know it
- Rethink everything, i.e., the whole paradigm
  - Forget Message Passing based IPC
  - Welcome Black board / tuple space based IPC
- Going deeper: not so different after all
  - Changes mostly APIs, naming and rendezvous
  - Results in large changes to the network economics
  - Allows (but not necessitates) rethinking everything

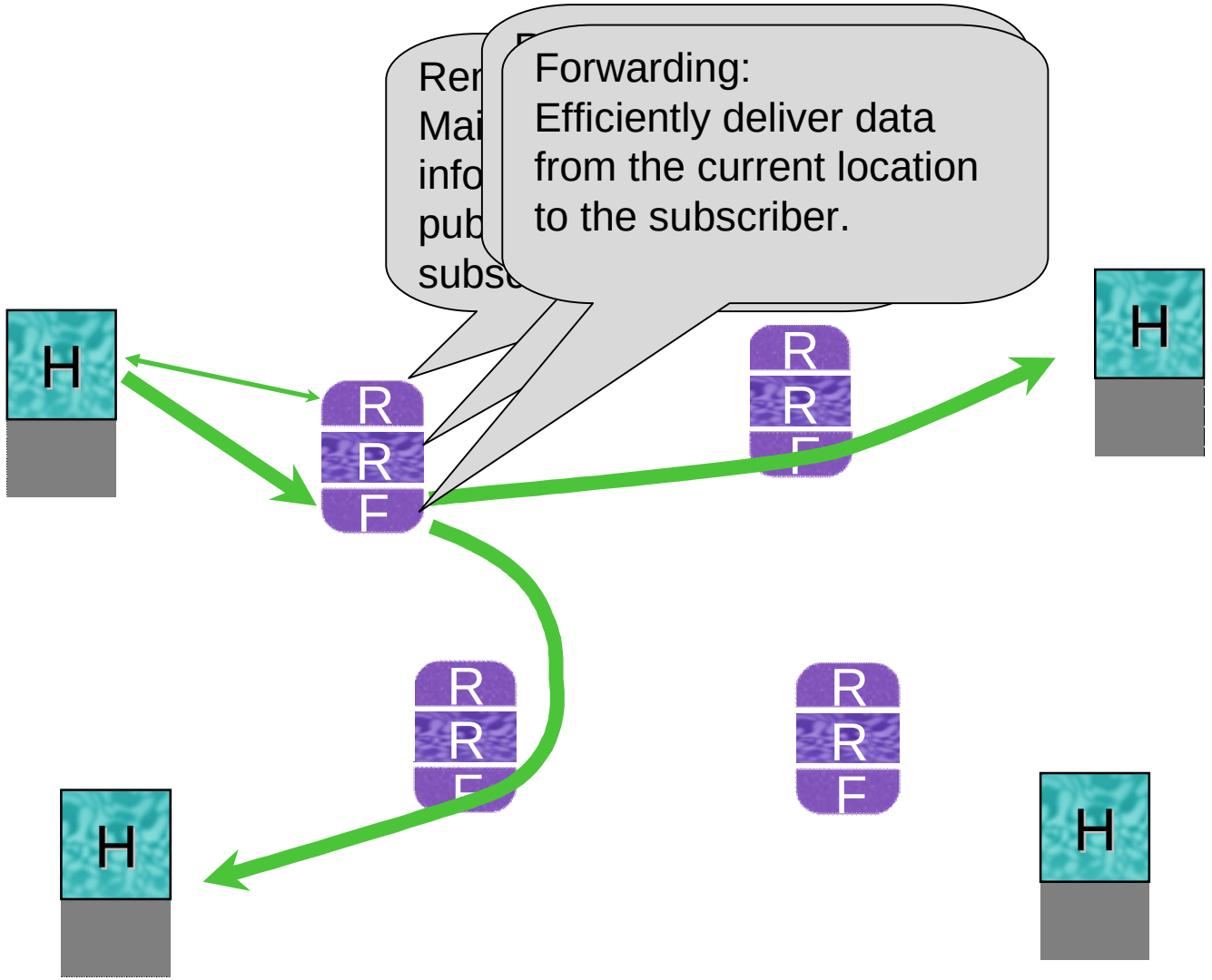
Why?

- Micro-economics: Prevents DDoS very effectively
  - sender does have incentive to send, always
  - receiver does not necessarily have incentive to receive
  - current networks help the sender
    - network forwards whatever senders send
    - “rendezvous” takes place at the receiver, with the receiver’s resources
  - from fundamentals: how would the network help receiver?
    - by allowing receiver to select what to receive
- Architecture: Unifies unicast and multicast
  - unicast becomes a 1-recipient multicast
  - makes radio and wireline more similar
- Applications: More natural to many applications
  - content delivery networks

Functional model



Three-layer architecture



Summary

Summary

- Internet is a critical backbone of the society!!!
  - Internetworking is needed also in future!
- Internet has grown out from its original design specifications
  - We need to address the problems so that we dont need to invent patches over patches over ...
    - NOTE: the core of the Internet hasn't changed in a > decade!
- Not only the problems of the current Internet are needed to consider.
  - Many Socio-economical, business, … are putting pressure on getting Next Generation InterNetworking solved in satisfactory manner.
- There exist many efforts to address the "problems"

... but one should also remember that it takes time and we must find ways to preserve the current internet until the new Future Internet is in place and serving us all! ☺

Thank you!

Questions?