## **Autonomic Communication**

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Fraunhofer Institute for Open Communication Systems



- Basic research in networking becomes a political priority
  - European Commission
    - FP6: 20 million € on situated and autonomic communication
    - FP7: autonomic management largest topic on Research Shopping List
  - US NSF GENI (~PlanetLab\_NG), FIND (~ EU Situated & Autonomic Communication), DARPA NewArch, XG programs
  - Germany: AC originated in Germany
- Industrial participation
  - AC Forum (200+ members, 90+ observers)
  - IBM, Hitachi, Cisco, Fujitsu, France Telecom, Deustche Telekom, ...
  - Motorola: Autonomic Communication Lab. (J. Strassner, est. 2005)
- Response from Academia
  - International conferences (4 in 2004, 39 in 2005) with AC topics
  - IFIP: Autonomic Networking conference (Paris, Sept. 2006)
  - IEEE Task Force on AC  $\rightarrow$  Technical Committee soon

## AC follows a pattern of a *scientific avalanche* – reaction of research community and political forces to industry demand



"The obstacle is complexity ... Dealing with it is the single most important challenge facing the I/T industry" Paul Horn, IBM "Technology needs to manage itself" Irving Wladawsky-Berger, IBM

"New EcoSystem is evolving, new ways of interaction, in which network orchestrates" Joelle Gauthier, Alcatel

> "Service creation at service element" Graca Carvalho, Cisco Systems

ICT complexity has to be appropriately handled at datagram level



## <sup>®</sup>Ozalp Babaoglu, UniBo

Self-organisation

Self-management **Self-awareness** Self-[re]configuration **Self-optimisation Self-healing Self-protection Self-adaptation (context) Self-description (openness)** Self-implementation

After http://www.research.ibm.com/autonomic/overview/elements.html

Autonomic

Communication



## What NSF says

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With the permission from the author Source: Guru Parulkar (NSF), The NeTS Program - **Broadly Defined Networking Research** 



## **Guru's Observation**

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With the permission from the author Source: Guru Parulkar (NSF), The NeTS Program

## Mesh Networking: Creativity

- Mesh Networking Research Challenges (as identified by Freifunk people)
  - Democracy: community self-healing (keeping the state of consistency)
    - C.f. anomaly detection, propagation of trust and danger models
  - "Kugel": optimised bandwidth usage
    - C.f. opportunistic radio (spectrum access)
  - Self-deployment: optimal coverage
    - C.f. co-design of protocols and topology

freifunk ı













### Embedded in Even Larger ICT



desired macro-behaviour



## NTT DoCoMo: Post IP





## NTT DoCoMo: Value Evolution

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With the permission from the authors. Source: Kazuo Imai, et. al., NTT DoCoMo, A Proposal for Expanding 4G Networking Towards the Ubiquitous Worlds, WTC/ISS 2004



- Approach Planned Evolution
  - 100 Mbps (triple play) of connectivity between all 100 Million American homes
- Holistic design

\$500B annual benefit to the U.S. economy [Brookings Institute, 2001]

- explicitly consider economics, dependability, and security issues while architecting the network
- Leveraging network structure
  - Co-design of topology and protocols

http://100x100network.org/



- Technology induced problem
  - Internet profit dilemma: carriers need to invest in the Internet infrastructure that is hard to charge customers for
    - Best-Effort
    - Lack of settlement interfaces
    - Convergence



Source: CIMI Corp



- Massively parallel and distributed
- 40 Gbps-capable line cards: processing for 100 million packets per second (pps)
   Datagram processing workflows
  - parsing, examining Layer 2 through Layer 7 information, prioritizing traffic to quality of service levels, assigning VPN IDs, classifying and filtering packets, and multicast functions, etc.
- "the next-generation router will be twice as fast as ASCI White<sup>1</sup> primarily because the router can scale to 256 or more 40-Gbps line cards – a phenomenal increase over today's routers"

Source: Performance similarities of nextgeneration routers and the largest supercomputers, by Dan Lenoski the vice president of engineering at Cisco Systems May, 12, 2004, http://bg.telephonyonline.com/ar/telecom\_performanc e\_similarities\_nextgeneration/index.htm Up to OC-768 Interfaces Route Processor(s)

Linecards (100's)

1. ASCI White - U.S. Department of Energy's Advanced Strategic Computing Initiative (ASCI) supercomputer



#### Wireless

Organic growth of coverage: 20 millions of installed APs, growth – tens of mio per year

### Mobility

Mobility management and mobility prediction are becoming ubiquitous services

### Immunity

Analysis of anomalous behaviour – business as usual for all network services and systems Controllable Affordable Dependable Ambient Networking

Net mining

Self-management by informed autonomic decisions through distributed continuous query processing

### Intelligence

Convergence

Support heterogeneity by built-in context handling and task-based data synthesis

Cost-aware policy-based selfmanagement structures based on emergent federations and governance hierarchies

After R. Katz, G. Karlsson, G. Leduc, G. Hjalmtysson, L. Mathy, G. Pujolle, T. Roscoe, R. Stadler, J. Strassner, C. Tschudin, K. Calvert, S. Fdida, D. Raz, S. Schmid, , H. Schulzrinne, B. Plattner, M. Sloman, and many others



## **Internet Patchwork**





# **Internet Complexity Measures**

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- Complexity ~ management and maintenance effort
- How many protocols an ISP needs to support? ~1400, but +
  - Standards 82
  - Draft Standards 69
  - Proposed Standards 797 (SIP, RTP, MPLS, RTSP, ...)
  - Experimental 175
  - Historic 86 (html v.2, snmpv2, X.500. BGP-OSP interaction,....)
  - BCP 82 (XML Registry, SIP Basic call flows, ...)
  - RFC Editor Queue: in total 211; 96 already approved

+ Internet Drafts + ...



- + IANA registered TCP/UDP port numbers: 8394 + ...
- + Number of protocol parameters:
  183 normative documents + ...
- + MIBs + ...
- + vendor specific solutions + ...
- + interop + ...
- + CRM (SLA, etc.) +
- + OSS + ...

1 id-index.txt



## With all this Complexity ...



- IP is a least common *functionality* for data transfer between heterogeneous link layer technologies
  - IP datagram is self-contained (header)
  - Supports exception handling (ICMP)
  - Capitalises on ubiquitous infrastructure (IP module)
- Can we do the same for network control & management plane? YES!



## **Responding to a Challenge ..**

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BM Autonomic Home	
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#### A Knowledge Plane for the Internet

David D. Clark\*, Craig Partridge\*, J. Christopher Ramming\* and John T. Wroclawski\*

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## Autonomic Communication fills the gap

With network selfware based on universal and fine-grained multiplexing of numerous policies, rules and events that is done autonomously but facilitates desired behaviour of groups of network elements.

#### MIDCOM

Let the communication infrastructure compute itself based on desired behaviours





Self-similarity of control plane



- Emergent Control Hierarchy Organisation ECHO
- Emergence of layers:
  - evolution at many layers
  - traditional middleware will create a layer on top of a protocol stack
  - network infrastructure evolution will create layers inbetween existing stack layers

"Sandwiched emergence" of layers

- a new abstraction layer
- [D. Lane] needs to create **two** interfaces

MPLS = layer 2,5IPSec = 3,5transport security = 4,5HIP = 3,5+

- Host Extension principle:
  - a host shall not depend on any type of infrastructure but can rely on it when eventually available:
    - Virtual servers (DNS, DHCP, CIB, ...) at each host are hooks of potential control trees rooted at host (e.g. LUNARng)





- Must keep adding levels of hierarchy to keep routing working
- Hierarchy squeezes the address space; each additional layer reduces total addressing capacity





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## ECHO: Evolution of QoS (2/2)

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## 42 years ago ...

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MEMORANDUM RM-3420-PR AUGUST 1964 Self-Learing Policy & Rules								<u>*</u>						

- "What is envisioned is a network of unmanned digital switches implementing a self-learning policy at each node so that overall traffic is effectively routed in a changing environment--without need for a central and possibly vulnerable control point"
- "The network can be made rapidly responsive to the effects of destruction, repair, and transmission fades by a <u>slight</u> modification of the rules for computing the values on the handover number table"

Source: Paul Baran, ODC, 1964, v.1. RM-3420-PR, ch4



### Local Self-adaptive Control Example

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## End-to-End in AC sense



The AC "end-to-end argument" postulates that no functionality, and/or intelligence that can not self-recover should be placed inside the network



Network operators are challenged by the Internet profit dilemma: lack of ROI in infrastructure upgrade, flat-rate crisis that is mainly due to the lack of settlement (wholesale) interfaces between operators. IPSphereforum.org perceives this as the main danger to the telecom sector. AC solution is SON as the Unit of Trade.





## **Multi-tier Dependencies**



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## SON as a Unit of Trade

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## **Node's Behaviours**

How many workflows? Just few! {receive [-classify] [-firewall] [execute][v4/v6 interop][SSL process] -forward [-meter -schedule] – transmit}

H. Hegde, Building an IPv6 Router, Proceedings of 2002 Communications Design Conference, Network Processing Forum



After: R. Kokku, T. Riche, A. Kunze, J. Mudigonda, J. Jason, H. Vin, A Case for Run-time Adaptation in Packet Processing Systems, ACM SIGCOMM Computer Communication Review, Volume 34, Issue 1



- Self-Management of network nodes
  - Distributed Task
    - not a single node does everything
    - every node according to its own capabilities
  - Self-Organize Roles of who's doing what
  - Self-Monitor for Failure and Auto-Correction



Role / Backup	N1	N2	N3	N4
V_A	0		Х	Х
V_B		0		Х
V_C	Х	Х		0
V_D	Х		0	Х

oneof-function for distributed role computation

### Self-Management=Context Awareness + Dynamic Role Assignment



Sharing the same motivation with IBM's Autonomic Computing (self-management of IT) Autonomic Communication's main goal is to enable in-network decision making that is challenged by incomplete or uncertain information



Autonomic Computing Autonomic Communication



## **Communities!**

AC Take community of features serving a single flow Better intrusion detection community of features serving all
community of features serving a single flow Better intrusion detection community of features serving all
community of features serving all
flows of the same class Better <b>resource manageme</b>
community of features empowered by IPFIX/PSAMP Better scalability
community of features involved in SLA provisioning and monitoring Better fairness

After: Michael Smirnov, Jon Crowcroft QoS Roadmap for Future Internet Services, in LNCS 2856

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## **Community Power**







## The road ahead



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## Thank you!

## http://www.autonomic-communication.org