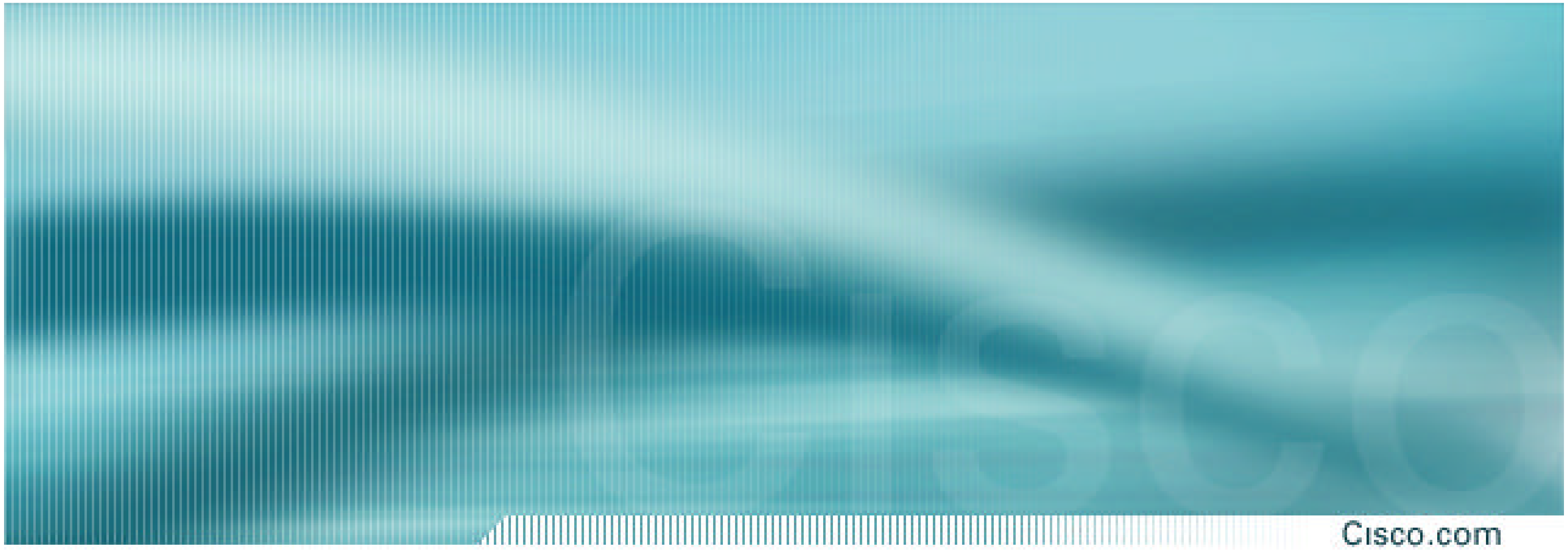

# The End To End Internet

**Harald Alvestrand**

**Cisco Fellow**

**IETF Chair**

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## Hat Identification

- Not speaking for Cisco (I don’t know what they are doing)
- Not speaking for the IETF (they don’t know what I’m saying)
- Speaking on the basis of experience and thinking
- Speaking as myself

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## The Original(?) Principle(s)

- If you need to do something at the end of a connection, why bother with doing it in the middle too?
- If you don't attempt to do in the middle what you have to do at the end, the network is simpler, more open and better
- Having application state in the network is stupid – keep it at the endpoints

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## Problem identification

- ”End” is a simple concept
- A process makes a connection, sends data, receives responses. The connection is end-to-end.
- Life isn’t always that simple.....

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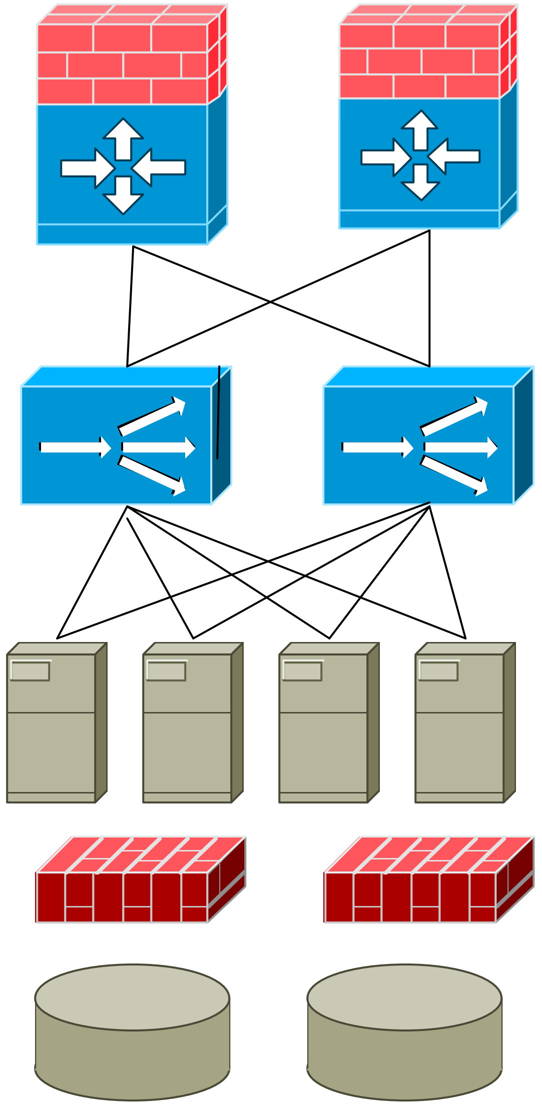
## A more real-life example

- To the outside: A single webserver
- On the inside: Duplicated everything, multilayer architectures.
- Where’s the end?



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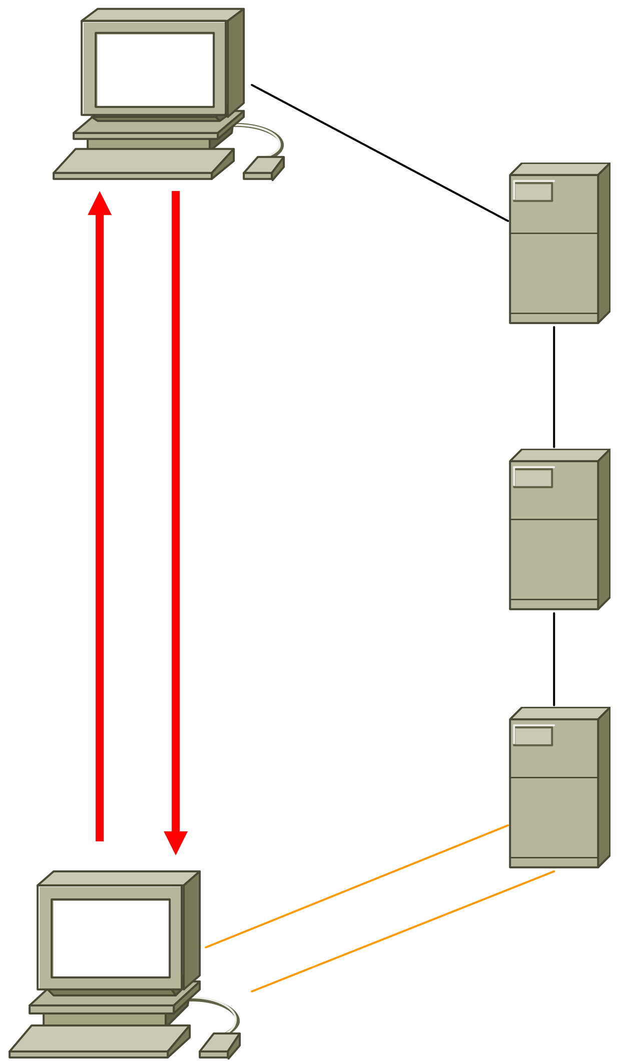
## Another example: Mail

- **Where's the end?**

**Mail traffic**

**SMTP traffic**

**POP traffic**



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## The two concepts of end-to-end (1)

- **Technical: That which cannot  be done well in the middle must be done at the edge.**

….functions placed at low levels of a system may be redundant or of little value when compared with the cost of providing them at that low level. (Chiappa)

The function in question can **completely and correctly** be implemented only with the knowledge and help of the application standing at the end points of the communication system. Therefore, providing that questioned function as a feature of the communication system itself is not possible. (Saltzer/Reed/Clark)

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## The two concepts of end-to-end (2)

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- **Moral: Network bad. Endpoints good; middlebox state bad; soft state good; stateless even better.**
- **This is a design choice. And it has served us very well. It is not a natural law.**

the intermediate packet switching nodes, or gateways, must not have any essential state information about on-going connections. Instead, they are stateless packet switches, a class of network design sometimes called a "datagram" network. (Clark95)

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## Digression: The Phone System Illusion

- The ”end” being an apparatus, not a person (earpiece, microphone and dial)
- End was ”obviously” stupid. All ”smarts” in the middle.
- A billing relationship implied by the physical wire and logical number plan
- Additional functionality being built on the trust relationship that was based on the wire
- Complexity (services, mobility) was added while keeping the basic model
- As a single model, it worked fairly well

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# Phone Systems in Trouble

- The PABX: Groups of endpoints????
- Interconnection: do you trust your competitor/customer/provider?
  - See MCI local-call case
- Intelligent endpoints using the phone network as dumb carrier: Dialup ISPs
  - Lots of work to stop the network from being too smart
  - ”To disable call waiting: ....:”
- Telco bypass: Voice over the Internet
  - Within and outside the E.164 dialling plan
- All signs that the marriage of functionality and connectivity was artificial and ill-funded.

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## Does end-to-end always work?

- Stupid Endpoints

  PDAs, mobile phones, appliances

- Security imposed from the middle

  Firewalls, authenticating proxies

- Performance issues at special points

  Wireless links, fast long-delay links, congestion points

- Money/control issues

  Those who can deliver a more complex function can demand more money for it (both groups!)

- NAT!

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## Stupid Endpoints

- ”Lightweight” devices connecting to a network

  Can’t authenticate, can’t encrypt, can’t remember

- ”Solution”: Tie them to a larger system
- Force all communication through this intermediary
- Works for GSM signalling
- Functionality totally dependent on intermediary
- In many cases, example of ”distributed endpoint”

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## Security in the middle

- Network owners want control
- An open architecture loosens control
  - Ethernet jacks
  - Standard PC architectures
  - Windows
- If you cannot control the endpoint – control a chokepoint
- Problem for security: Security!
  - Encrypted sessions are a major problem
  - End-driven key management is even more of a problem: No way to check what’s going on!

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# Performance issues

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- Long-delay pipes
  - Sending (or pacing) ACKs can increase performance, without upgrading end systems
  - Content distribution networks move content ”closer” to the consumer than the originator can
- High-loss, low-bandwidth networks (”wireless”)
  - Content adapters (”HTML downgrade” ++)
  - Defeat TCP’s ”all loss is congestion”
  - (Un)fairness based on identity
- There are other solutions to most issues
  - Diffserv/RSVP, Fast-TCP, .....
- Content adaption can be seen as ”split endpoint”
- Lack of model clarity is one of the bigger dangers here

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## Money/Control issues

- Desire of service provider: Get more money.
- Desire of equipment provider: Get more money.
- Method often used: Sell more complexity.
    - Service provider: Fancier services (in network)
        - Diffserv, Provider VPNs, voice-over-IP, managed services....
    - User side: Fancier services (at endpoint)
        - User VPNs, user voice-over-Internet, firewalls, scanners....
- If offering is unique, and customer buys it, customer can’t escape. Price no longer decides.
- This is, long-run, a false way
    - Competition will take care of those who spend too much
    - Useful services will be used more, expanding the market
- In the short run, it works.

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## So are there answers?

- Valid architectures are those that provide value to the end-user
- Some services require middlemen

  The DNS service is a middleman

  So is the telephone numbering system
- Open architectures encourage the pieces to be considered separately

  Cross-subsidy is not a stable model – see DNS, voice-over-IP services

  Attempting to block services is Not Good

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## So what is an ”end”?

- Dependent on context
- Related to function

    ”end” of reliable byte delivery is not the ”end” of database transaction processing, which is not the ”end” of an email conversation

    Clark et al knew this in 1981. We sometimes forget – and our systems work well enough that we often get away with it.

- Needs clear thinking to identify

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## Trust and the Principle

- End users have to extend trust in order to get work done
- Middle-box security tries to force the issue, but can’t know what the end-users are doing
- The Right Way is for the ends to extend trust, and tell the middle that they are doing so
  - With the required authorization
- This is the end-to-end principle again!

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## What does an ”end” look like?

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- Commonly under a single administration
    - Or seen by others as a single entity
    - This is core to keeping innovation running
- Contains all the parts needed to perform its part of an useful communication function
    - May have internal structure
    - May rely on other srevices
    - Does not force others to know about this structure
- Depends on your layer of abstraction!

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## The End of the End Is Not Near

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- We build services at many different levels
- We need to be aware of the ”ends” we create in making those services
- The end-to-end principle is a design tool
- Do the right thing. Once. In the end.

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