

Evolution of Networking

Current Problems and Future Directions

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Dr. Pekka Nikander,

Ericsson Research Nomadic Lab

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Introduction

- Once upon a time...



- Once upon a time...



How to realise interconnected information?

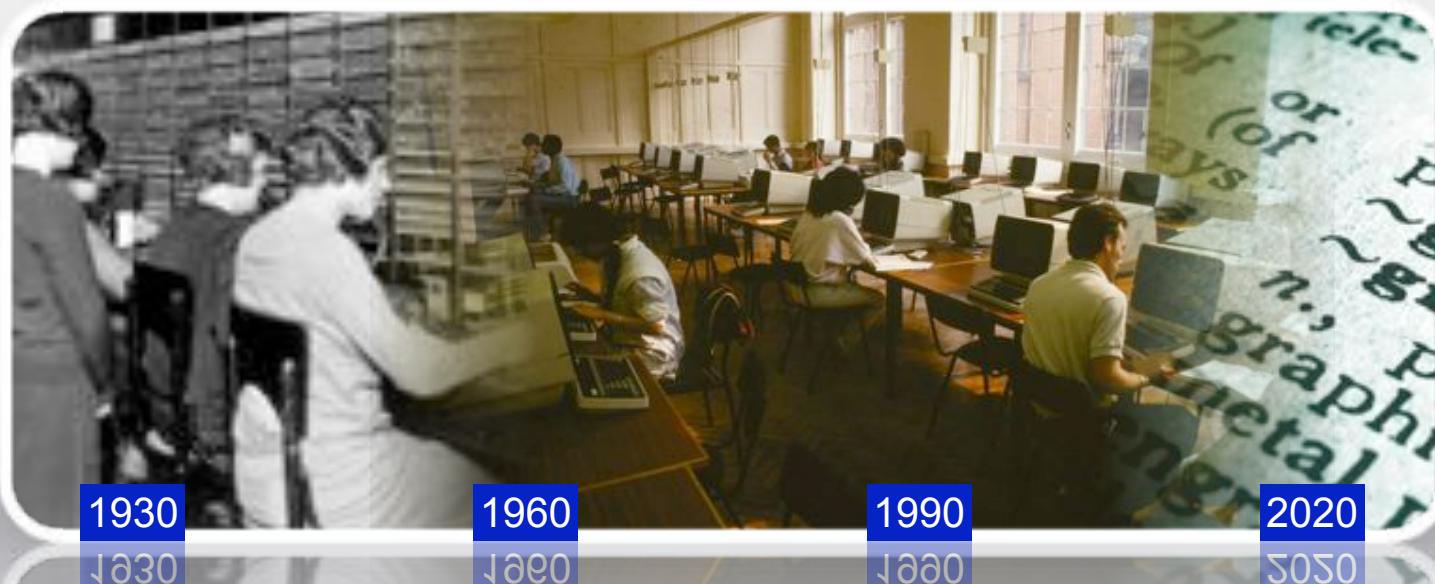


- ... considering that we are mere humans ...
- ... considering that we are

Outline

- Three waves of networking
- Current problems
- Research directions

Three waves of networking



The First Wave: Wires

- Connect wires to other wires
 - Wires to every home and office
- Encourages monopolisation
- No need to go any deeper there



The Second Wave: Nodes



The Second Wave: Nodes

Change of the paradigm

- Killer app of 1980s: Remote access
- Focus on end-points (minicomputers)
- Use existing wires, but differently
- Encouraged distributed operations
- Adaptive routing increased reliability exponentially as the number of routers and links grow
 - But then we hit the limits of scalability and business
- No call set up → high efficiency

The Second Wave: Nodes

TCP / IP issues

- You are either connected or not
 - Either you have a routable IP address or not
 - Connecting is relatively heavy-weight operation
- Success created a new class of problems
 - Scalability, mobility and multi-homing, security
 - Emergent properties, e.g., hotspots, unwanted traffic
- TCP tuned for remote access
 - Not good for real time, not very good for disconnected operations

The Third Wave: Information



- Content Centric Networking
 - Van Jacobson, PARC
 - Build on top of the Internet, like the Internet was built on the top of wires

The Third Wave: Information

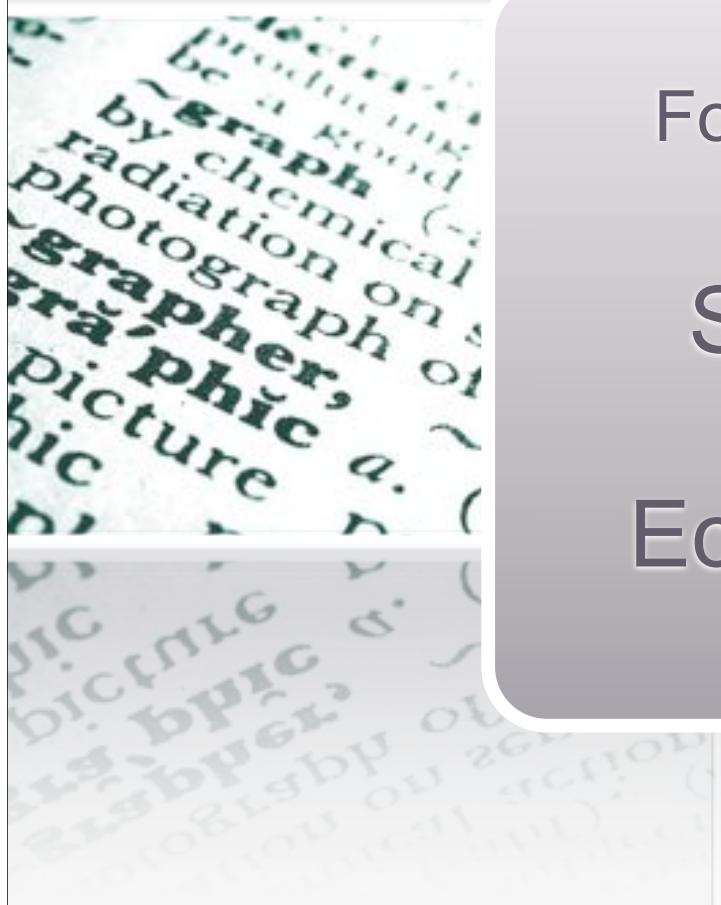


- Content Centric Networking
 - Van Jacobsen, PARC
 - Build on top of the Internet, like the Internet was built on the top of wires
- Our aim is to be more radical...

The Third Wave: Information

Focus today: Security & Economics

Networking
PARC
the Internet, like the
t on the top of wires
e more radical...



Outline – again

- Three waves of networking
- Current problems
- Research directions

Current problems

Unwanted
traffic



Resources
& Com-
pensation



Trust &
Reputation



Privacy &
Attribution



Unwanted traffic

- Spam, DDoS, Phishing, ...
- Root cause in economics
 - Marginal cost of sending is lower than marginal cost of receiving
 - The prime example of current, negative externalities



Resources and compensation

- Long and short term shortage
 - Short term shortage ≡ congestion
- Resolve congestion through compensation (market arbitration)
- Structure compensation to encourage capacity growth



Trust and reputation

- Strong reciprocity
 - Willing to trust, altruistic punisher
- Dunbar's number: 150
- Social mechanisms for reducing cognitive load



Privacy and attribution

- Transparent society unattainable
 - Powerful can always afford privacy
- Privacy into a basic characteristic of the network
- Balanced with accountability



Outline — once more

- Three waves of networking
- Current problems
- Research directions

Focus for what follows

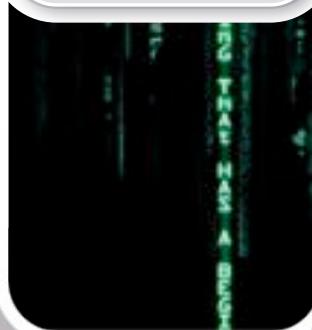
How these directions
do in the light of
previous problems?

Research Directions

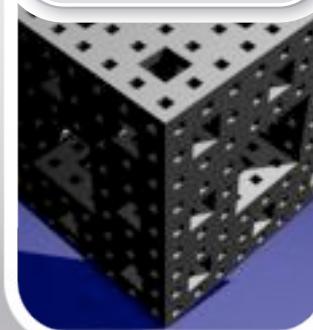
Middle & Overlays



Virtualisation



Recursive Layerless



Networking of Information & Computation



Middle boxes and overlays



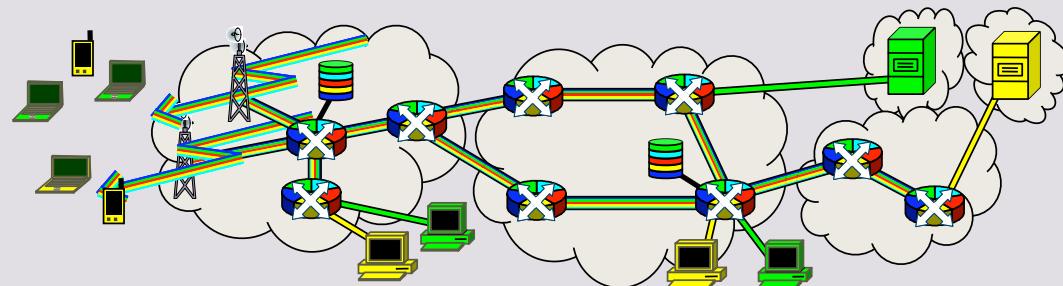
Virtualisation



Virtualisation

Parallel virtual networks

- Multiple network stacks
 - Easy to install new stacks
- Independent evolution
- Allow contradictory requirements
- Single infrastructure
- Pluralism
- Isolation
- Customisation
- Amortisation



Virtualisation

Ongoing and planned projects

- **VINI — Virtual Network Infrastructure**
 - 26 nodes at 16 sites in the National LambdaRail and Internet2
- **CABO — Concurrent Architectures are Better Than One**
 - NSF NeTS FIND: Rexford, Freamster, Gao
- **Diversified Internet — an architecture for**
 - NSF NeTS FIND: Turner, Crowley, Gorinsky, Lockwood
- **4WARD**
 - EU FP7, negotiation phase: Ahlgren, Dam, Feldman, Ohlman, Pink, ...

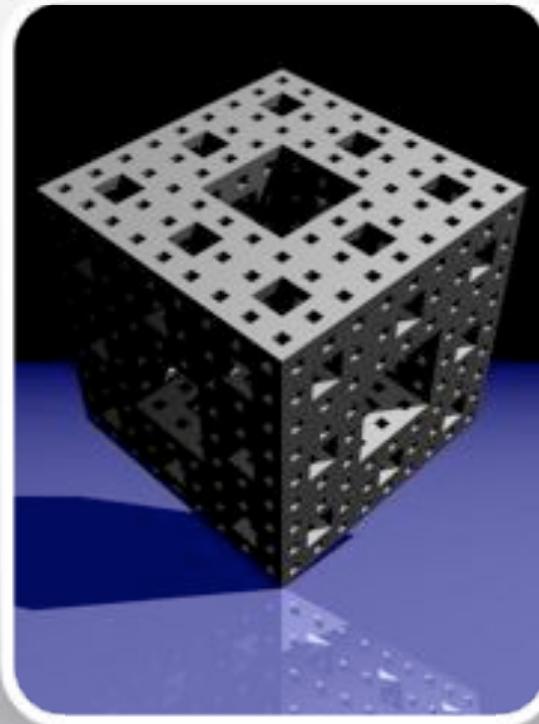
Virtualisation

Relationship to the present 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

Recursive and Layerless

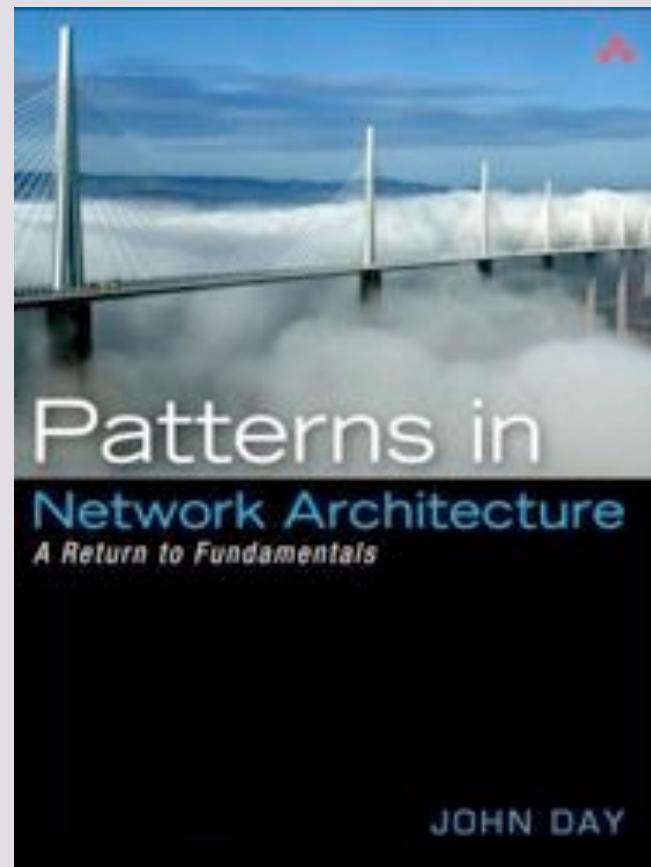
- One layer with plugable and tuneable mechanisms...
- ... or mechanisms / managers that can be plugged together
 - State management,
End-to-end congestion control,
Switching / forwarding



Recursive and

Recursive functionality

- Two sublayers
 - Error control & Congestion control
 - Routing and addressing
- Different strategies at different layers
- Identity/Location Resolution
 - The glue between layers



Recursive and

Existing projects

- **Haggle**

- EU FET project on Situated and Autonomic Communications
 - Quite large, lots of people involved (about 25)

- **RNA — Recursive Network Architectures**

- NSF NeTS FIND project on Exploring Layer Interactions

- **SILO — Service Integration, control and Optimisation**

- NFS NeTS FIND project: Rouskas, Dutta, Stevenson

Recursive and

Relationship to the present problems

- Does not directly affect unwanted traffic, compensation issues, trust and reputation, or 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

Networking of Information

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



Networking of

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, sub 200 ms latency, person-to-person traffic
 - Not good for non-real-time, cacheable, just-in-time objects
- Routing and addressing needs to be rethought
 - How to find data, not hosts

Networking of

Existing and planned projects

- Content centric networking (Van Jacobsen's; already mentioned)
- Postcards
 - NSF NeTS FIND project: Yates, Kursoe, Raychaudhuri
- Data Oriented Network Architecture (DONA)
 - ICSI activity: Shenker, Stoica, Ermolinsky, Koponen
- Service Centric End-to-End Abstractions
 - NSF NeTS FIND project: Wolf
- Publish-Subscribe Internet Routing Paradigm (PSIRP)

Networking of

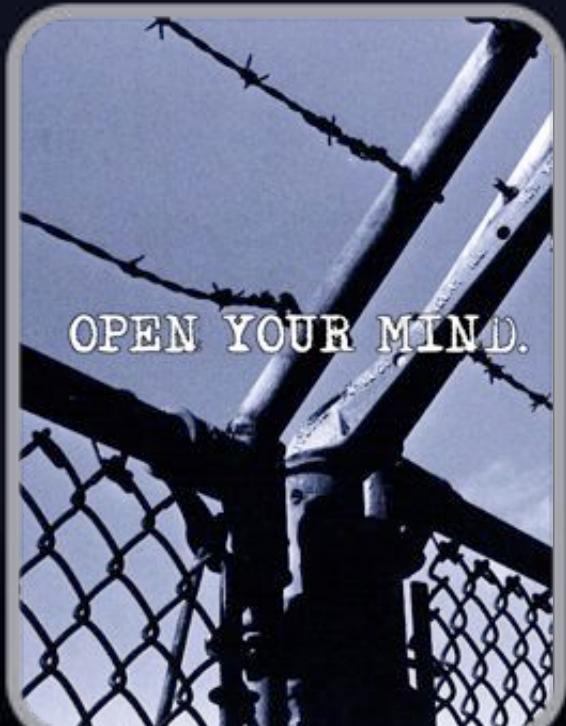
Relationship to the present problems

- Unwanted traffic
 - Makes some forms impossible (DDoS); changes dynamics of others
- Resources and compensation
 - Becomes more important than before; mandates creation of markets
- Trust and reputation
 - Focus shifts from nodes to information and actors
- Privacy and attribution
 - Changes nature completely but persists as a problem

Publish—Subscribe

- “Old” as an overlay
- Our idea: Across the whole stack
 - All layers from physical to application
 - Inherently multicast
- The challenge: scalability





Rethink the fundamentals

- Resources and locations
- Basic primitives
- Placement of state
- Identifiers and reachability

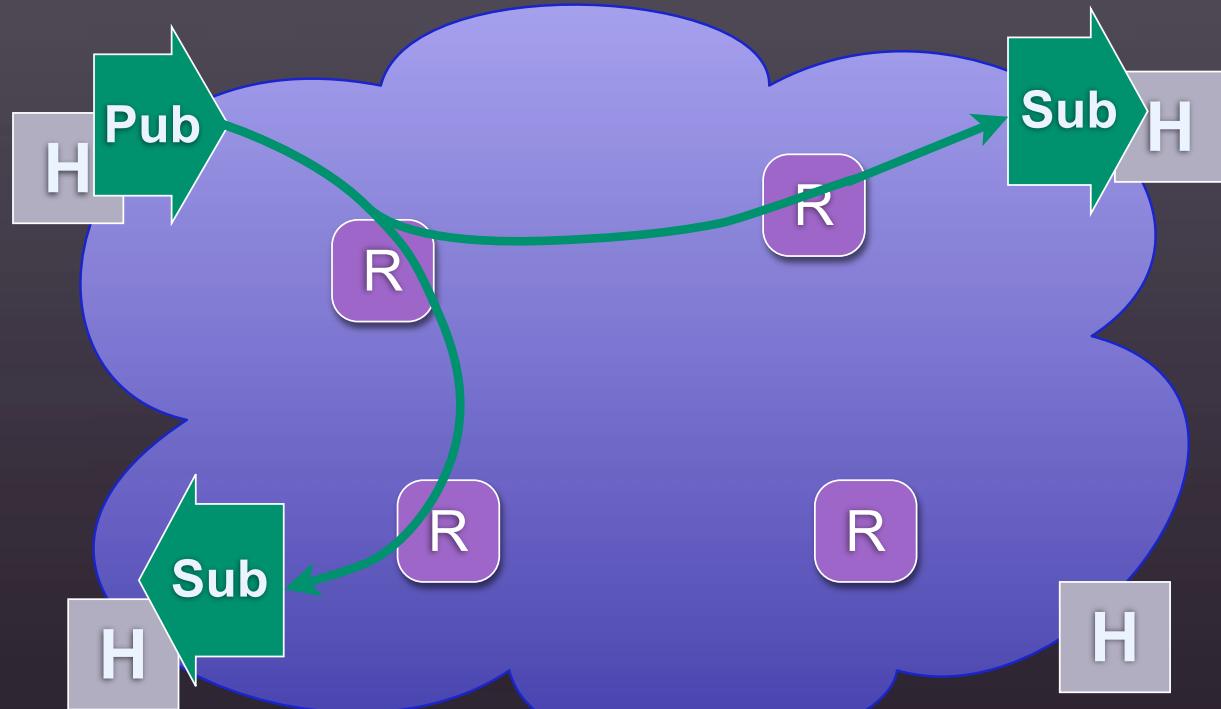
Rethink the

Think different

- 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 (publisher) and recipient (subscriber) needed
 - No more possible to send completely unwanted traffic
- Tuple spaces replaces message passing

Rethink the

The model



Rethink the

Technical background

- Current networking is an extension of the message passing
 - Network helps the sender
 - Rendezvous at the receiver
- Pub–sub is an extension of tuple space / black board IPC
 - Network consults both the sender and receiver
 - Rendezvous in network, close to the sender
- No need for network to have its own policy
 - Intention neutral, promotes innovation

Summary





The End