Advanced Internet and IoT Technologies

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Organisation of today‘s meeting

1. Introduction of Participants
2. Master Specialization & Course Organization
3. Introduction to the Internet Ecosystem
4. A Glimpse at the IoT

MUTUAL INTRODUCTION

The INET Group

inet.haw-hamburg.de

We work on

Protocols & Standards

Applications & Analyses

Systems & Security

on the Internet

INET is home of …

CAF: C++ Actor Framework

RTRlib.
The RPKI RTR Client C Library.

Overview of

MASTER & COURSE ORGANIZATION

Master special: Network-centric and time-critical systems

"The Network is the Computer"

- John Gage

- Selected Aspects of Cyber-physical Systems
- Advanced Internet and IoT Technologies
- Real-time Systems
- Network Security and Measurement
- Protocol Engineering
- Distributed Adaptive Systems

Time schedule & assignments

Course hours: Wednesday 9:00-11:30

- Lecture/discussion
- Paper presentation/discussion
- Lab work/discussion

Assignments

- Prepare lecture, paper, background
- Work on lab tasks & projects
- Present a paper of the week
- Present your contribution to IoT project

Paper of the week

Everybody reads the paper before class.

One assignee prepares presentation according to the following 5-slide structure:

1. Title slide
2. Problem slide: What is addressed?
3. Methodology/Solution slide:
   How is the problem addressed?
4. Evaluation slide:
   What are the key findings?
5. Slide of 3-5 discussion questions

Lab assignments

Lab experiments will be assigned early
→ check webpage

Group projects will be fixed in KW19
→ prepare and discuss ahead

Lab- and project work will be part of most class hours

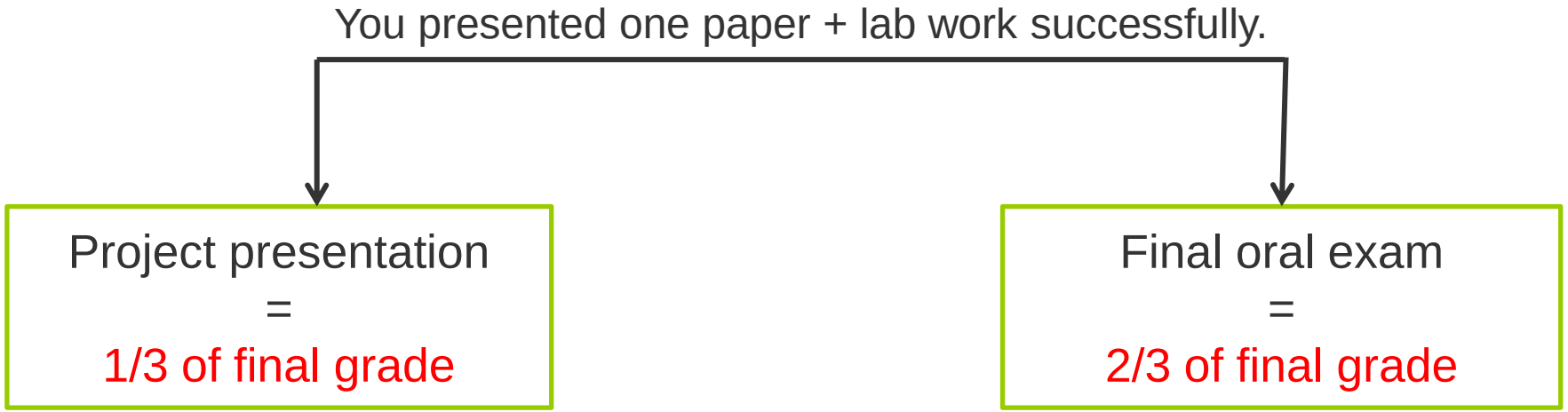
→ quick way to clarify and exchange in sync

You can work on the project any other time

You need to actively present progress results

→ during class hours

Grading



You NEED to register online in StiSys (legally binding).

Office hours, communication, and Web resources

Thomas Schmidt (lecture)

- Consulting hours: per email
- Room 480a
- T.Schmidt@haw-hamburg.de

Michel Rottleuthner (labs)

- Consulting hours: per email
- Room 481a
- Michel.Rottleuthner@haw-hamburg.de

Course homepage: https://www.inet.haw-hamburg.de/teaching/ss-2022/ti/

- Tools & Announcements
- Links to slides, recordings, papers, background, and assignments
- Teams forum for Q&A
  - Don’t be shy and ask your questions
  - Don’t be hesitant and help your fellow students

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Introduction to

INTERNET TECHNOLOGIES

Networking is a long-standing desire

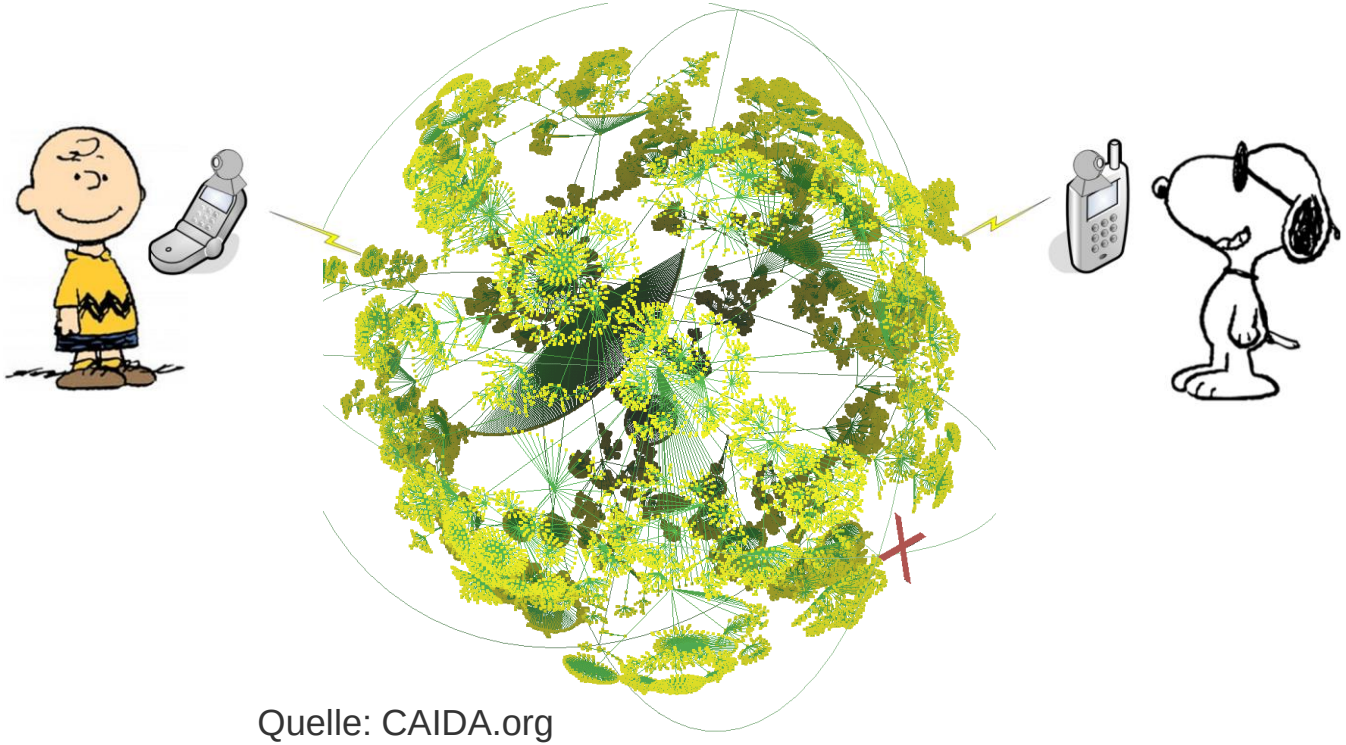
Optical telegraph lines were operationally installed more than 200 years ago – for long-distance communication!

Internet design goals since more than 40 years ...

+ Global reach w/ integrity – any two endpoints can exchange information
  + *implicit: globally-unique addressing and naming services*
+ General purpose use - no persistent favourites
  + *no inherent preferences or limitations on applications or services*
+ Permissionless innovation – new services easy to establish
  + *no barrier for service entry or application deployment*
+ Accessibility – anyone can connect anywhere for any purpose
  + *inherent: open to adding nodes and attaching new networks*
+ Interoperability w/ agreements – cooperatively designed for collaboration
  + *a network of autonomous networks that agree on standards*

The Internet is not the World Wide Web, nor facebook, or Google.
The Internet enables Services such as the World Wide Web **on top**.

We change perspectives



Quelle: CAIDA.org

The Internet was designed as a distributed system

End-To-End Arguments in System Design

J. H. SALTZER, D. P. REED, and D. D. CLARK
Massachusetts Institute of Technology Laboratory for Computer Science

This paper presents a design principle that helps guide placement of functions among the modules of a distributed computer system. The principle, called the end-to-end argument, suggests that functions

ACM Transactions on Computer Systems, November 1984,
https://doi.org/10.1145/357401.357402

there is a list of functions each of which might be implemented in any of several ways: by the communication subsystem, by its client, as a joint venture, or perhaps redundantly, each doing its own version. In reasoning about this choice, the requirements of the application provide the basis for the following class of arguments:

The function in question can completely and correctly be implemented only with the knowledge and help of the application standing at the endpoints of the communication system. Therefore, providing that questioned function as a feature of the communication system itself is not possible. (Sometimes an incomplete version of the function provided by the communication system may be useful as a performance enhancement.)

We call this line of reasoning against low-level function implementation the *end-to-end argument.* The following sections examine the end-to-end argument

Networking Research?

Networks are the backbone of Computing

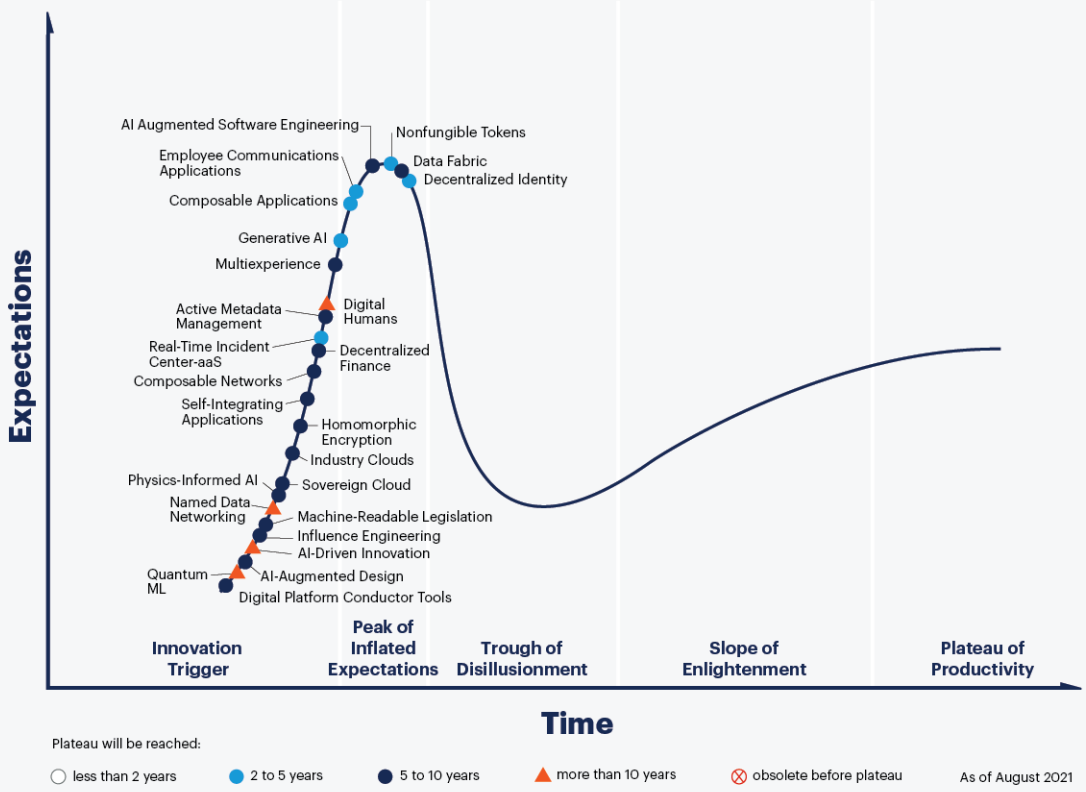
Almost all current trends are networked

- Distributed Computing
- Big Data
- Cloud Computing
- Internet of Things
- Smart Cities, Cars, Homes, …, AI

Network-centric companies are most valuable:

- Apple needed the iPhone to reach value
- Microsoft needed the Cloud
- Google, Facebook, Amazon network

Hype Cycle for Emerging Technologies, 2021



gartner.com

Gartner

What does Smart mean?

In the old days:

- „Can think“ → Computing, AI
- „Can remember“ → Storage, Databases

Today:

- „Can quickly locate“ → somewhere
- „Can delegate task“ → remotely
- „Can connect“ → anywhere

The network is the computer

John Gage, Sun Microsystems, 1984

Internet Business

The open, universal availability of the Internet has threatened business:

- Proprietary communication services

It opened a new ecosystems of (small) businesses

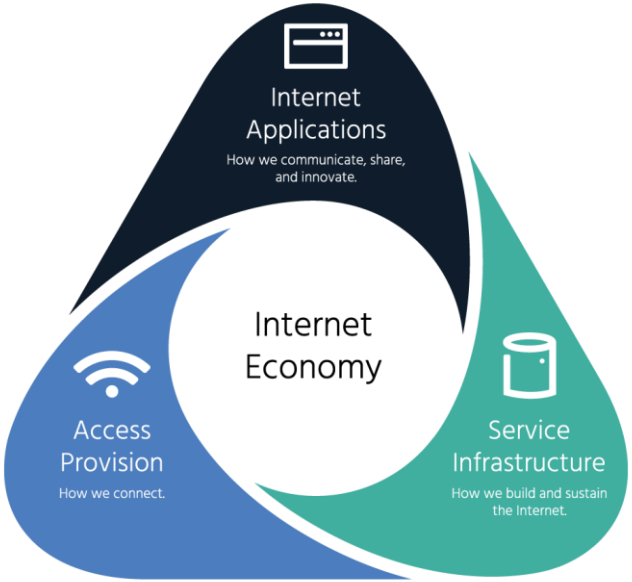
- Breaking up Pareto‘s law: „Living on the long tail“

It is about to generate new monopolies

- Indirect „Multiparty Models“
- Revamp of Internet Service in proprietary settings

Currently, the abandonment of standards by big companies, popular applications, and its users is the largest threat to the Internet

Business as a Problem for the Internet?



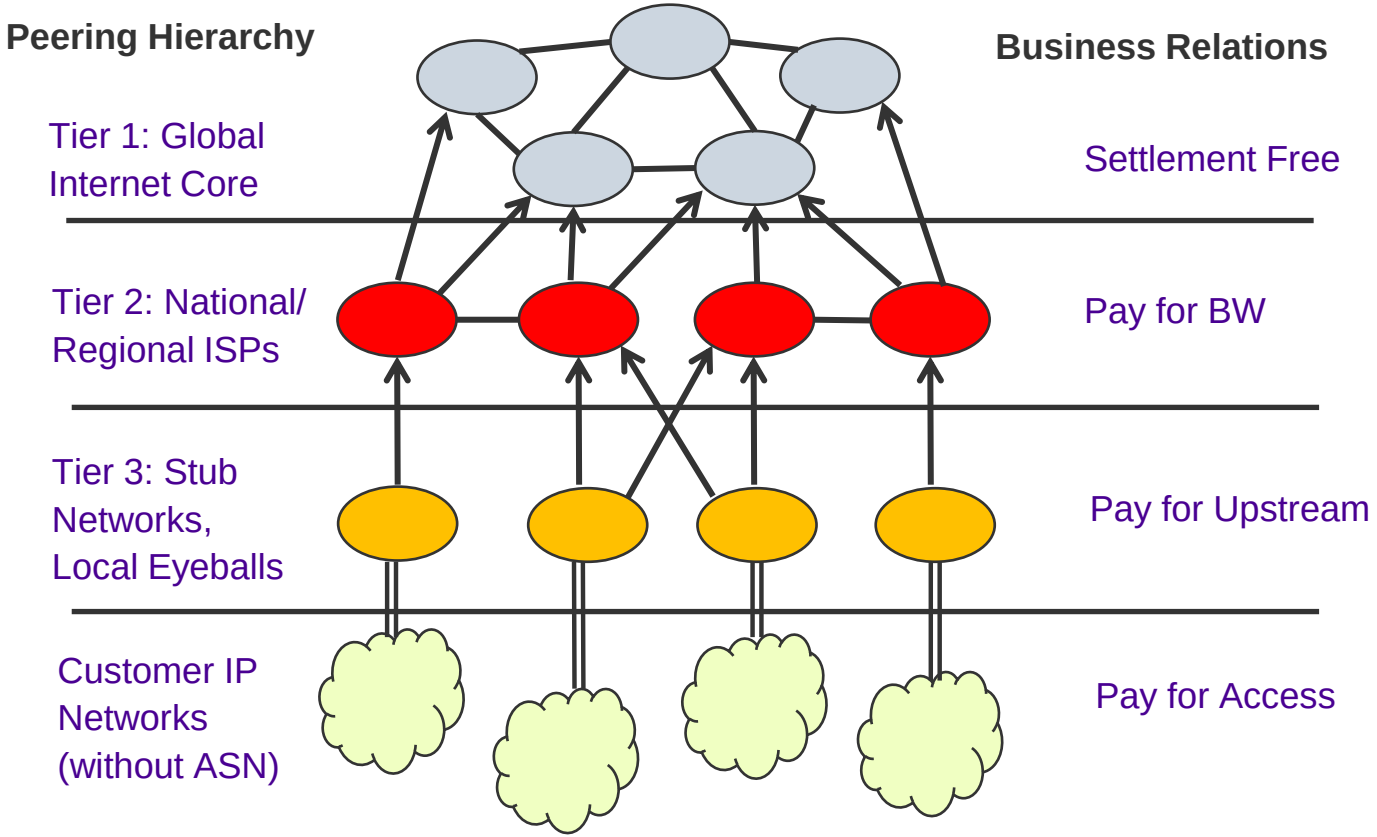
Source: ISOC Internet consolidation report 2019

The Internet Ecosystem is changing

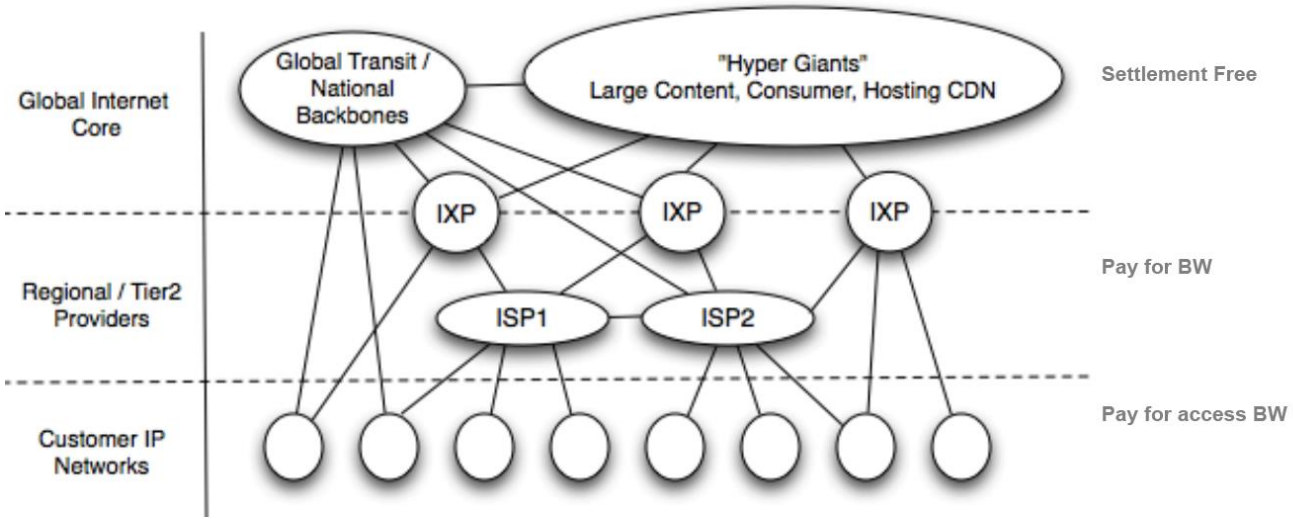
- At the Internet Edge
- In the Internet Core
- At application services
  OTT: Over The Top services
- In its use
- In its misuse

The Internet economy comes of age ... with a strong tendency to monopolize

Traditional Internet Hierarchies

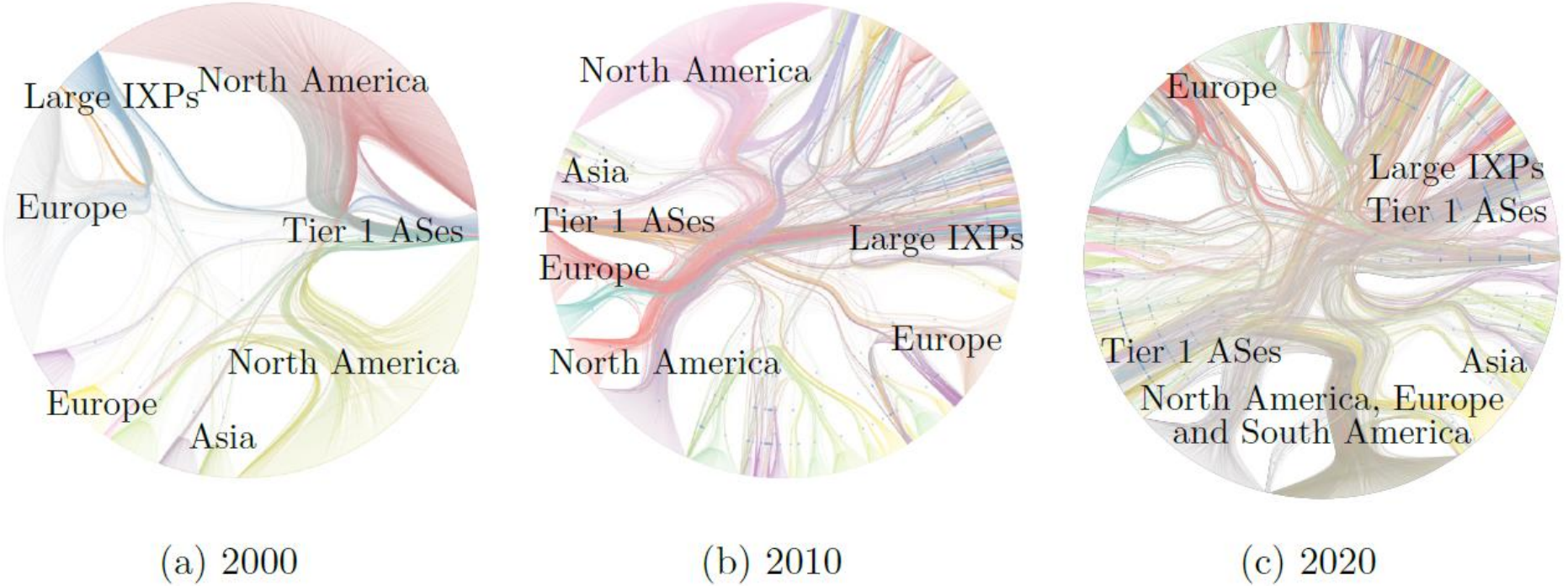


Flattening Internet Topology



Quelle: G. Labovitz, et al.: Internet Inter-Domain Traffic, SIGComm 2010

The Internet merges and grows together



Is the Internet flat?

Not really

IXPs are local

The Internet is global

Internet Core

Tier1 ISPs: Highest capacities in private peering
- Global presence, shrinking market
- Consolidation by fusion
- Manly complemented by access (Eyeballs)
- Customer base exploited for paid peering

IXPs: some large (transcontinental) growths
- Roll-out of L2 infrastructure reduces hops
- Peering at (large) IXPs grows expensive

Internet Edge

Eyeballs‘ strength: number of end customers
- Exclusive outreach is market potential

Regulation against conflicts and monopolies
- Last mile & radio frequencies

Disproportional growths at Internet edges
- Bandwidths, customers, end node capacities
- Significant threats: Botnets/Exploits, DDoS (Gamer)

OTT Content Distribution

Internet content popularity is Zipf-distributed

- Popular content is cacheable

Content distribution dominated by the BIG-7:

- Akamai, Amazon, Apple, Facebook, Google, Microsoft, Netflix

All seven built their own CDNs

- MULTI-CDN deployment: Core (own), edge (other) ... expansion strategies toward edge

Pervasive Encryption prevents caching at ISPs

Perspective of the OTT Service Operators

Indirect business models

- Customers pay to advertisers
- Special: Amazon

Accumulation of personal and behavioral data

Data analysis to

- Personalize ads and market research
- Successional exploitation
  ➔ Cambridge Analytica

Business fundament: Information Asymmetry

Investment Strategies of the OTTs

Dominate IT-Infrastructure
- Few can operate global (cloud) infrastructure

Control base infrastructure
- Build own cable/wireless infrastructure
- Buy (shares of) cable providers

Control end systems
- OSes, Browsers (+ content servers)
- Grants deployment sovereignty

Consequence: ISPs pushed into sandwich position

Amazon
- Hawaiki (major capacity buyer)
- JUPITER (part owner)

Facebook
- AEConnect (major capacity buyer)
- Asia Pacific Gateway (APG) (part owner)
- MAREA (part owner)
- Pacific Light Cable Network (PLCN) (part owner)
- JUPITER (part owner)

Google
- FASTER (part owner)
- INDIGO-Central (part owner)
- INDIGO-West (part owner)
- Junior (sole owner)
- Monet (part owner)
- Pacific Light Cable Network (PLCN) (part owner)
- Southeast Asia Japan Cable (SJC) (part owner)
- Tannat (part owner)
- Unity/EAC Pacific (part owner)

TAT-14 retired Dec, 2020

Microsoft
- AEConnect (major capacity buyer)
- Hibernia Express (major capacity buyer)
- New Cross Pacific (NCP) Cable System (part owner)
- MAREA (part owner)

https://blog.telegeography.com/telegeographys-content-providers-submarine-cable-holdings-list

The Internet consolidates

Fewer and fewer understand the Internet ecosystem

Fewer are able to operate the Internet

Fewer profit (significantly) from the Internet

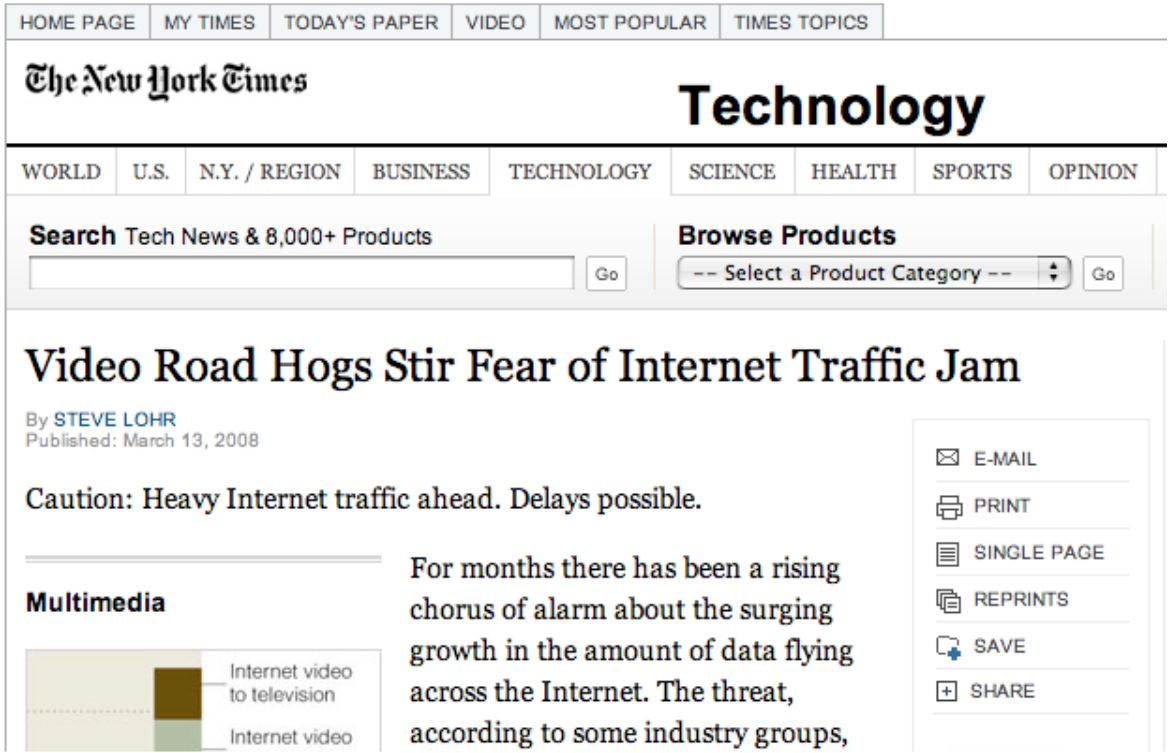
Snowden nightmare turned into a boomerang

> “
>
> ...Alphabet not only operates an online advertising platform, but also a search engine, a mail platform, a document store, a cloud service, a public DNS resolver service, a mobile device platform, a browser, and mapping services to name just a few. It appears that in this case, it is one enterprise with engagement in many discrete activities. The issue with consolidation is whether these activities remain discrete activities or whether they are being consolidated into a single service.
>
> —Geoff Huston, RIPE NCC, December 2018

Unique potentials of the Internet

- Global ubiquity
- Mobility
- Service adaptivity
- Group communication

The Video Tsunami



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Video Road Hogs Stir Fear of Internet Traffic Jam

By STEVE LOHR
Published: March 13, 2008

Caution: Heavy Internet traffic ahead. Delays possible.

Multimedia

Internet video to television

Internet video

For months there has been a rising chorus of alarm about the surging growth in the amount of data flying across the Internet. The threat, according to some industry groups,

E-MAIL
PRINT
SINGLE PAGE
REPRINTS
SAVE
SHARE

Audio + Video on the Internet?

A long story:

1981 – Packet Video Protocol (PVP), ISI/USC

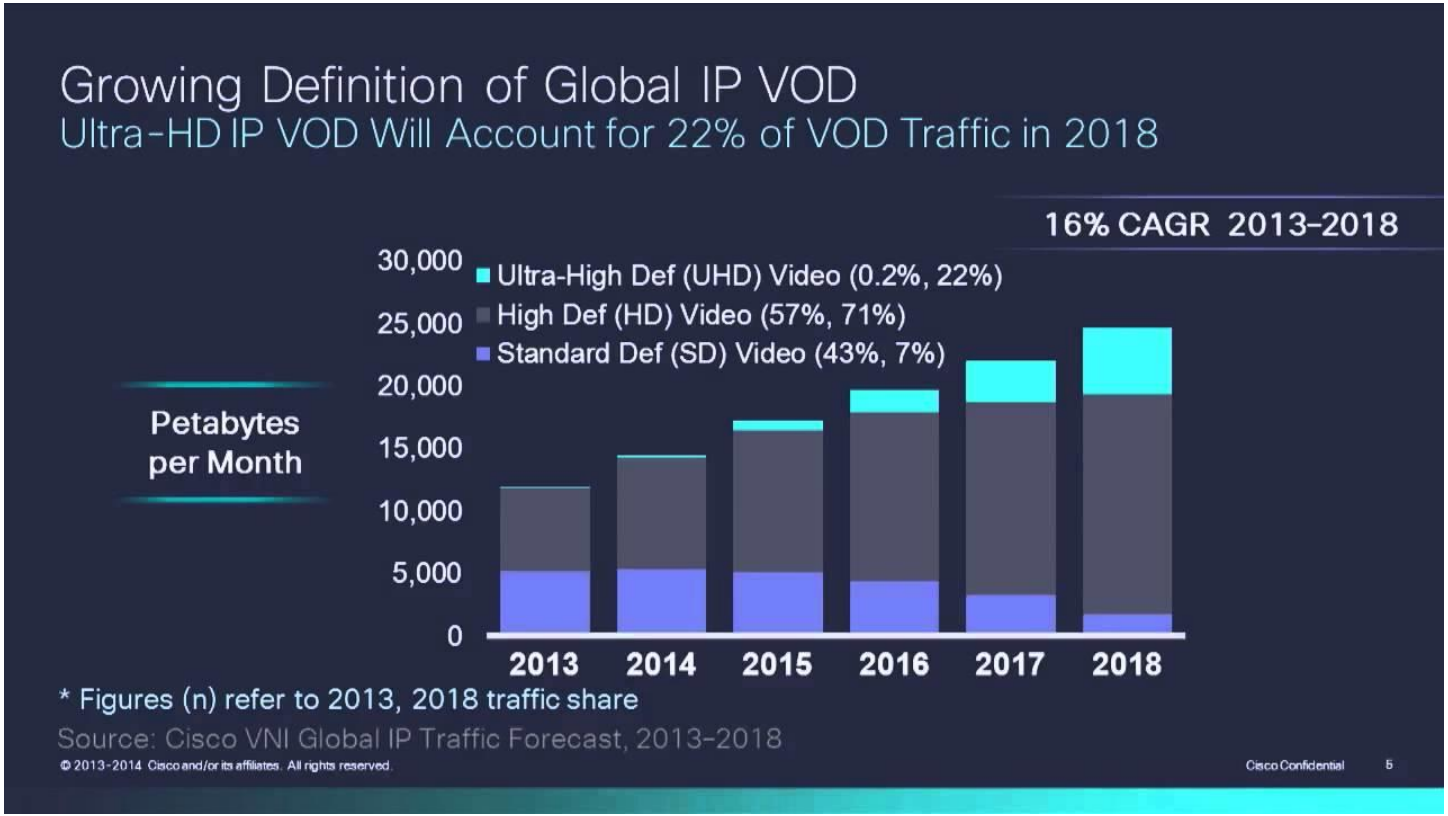
1990 – Internet Stream Protocol II – IPv5 (RFC 1190)

1991 – First Video Conference in DARTnet

1992 – Casner/Deering (ACM SIGCOMM CCR):

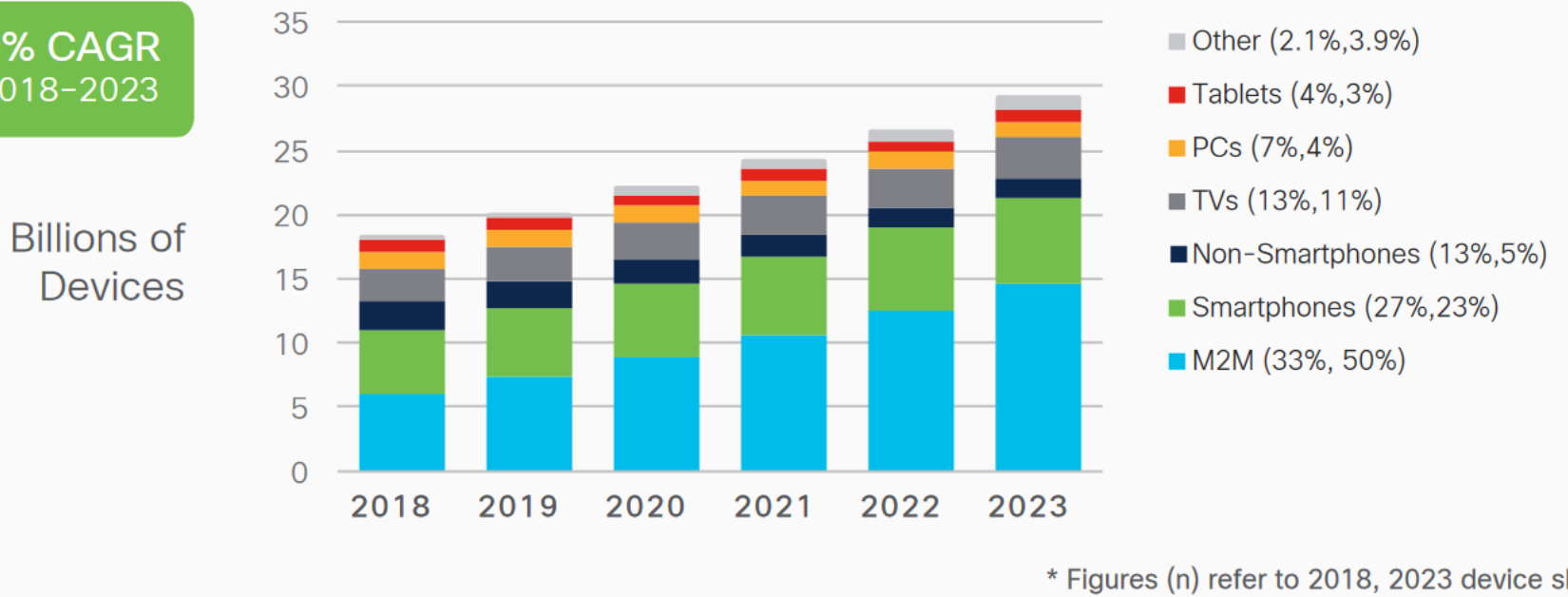
„At the March, 1992 meeting of the Internet Engineering Task Force (IETF) in San Diego, live audio from several sessions of the meeting was "audiocast" using multicast packet transmission from the IETF site over the Internet to participants at 20 sites on three continents spanning 16 time zones.“

Data growth for VoD



Development of devices connected to the Internet

10% CAGR
2018–2023



* Figures (n) refer to 2018, 2023 device share

Source: Cisco Annual Internet Report, 2018–2023

The Internet scaling problems

Exponential user growth continues since decades (!) – this challenges the Internet architecture – key problems:

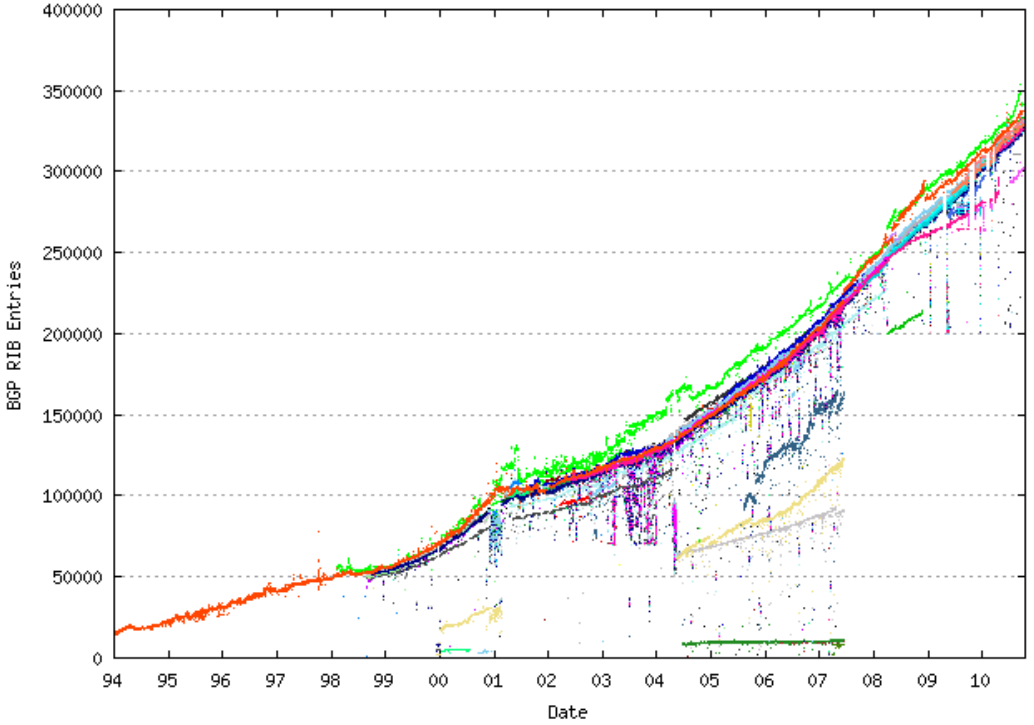
Addressing

Keep all Internet members reachable by a unique address.

Routing

Keep the Internet Routing and Forwarding system up to growing routes, updates and packet loads.

Routing Tables



ID-Locator Problem

IP packets issued to destination addresses.

Addresses denote the two

- the addressee (who it is?)
- the location (where it is?)

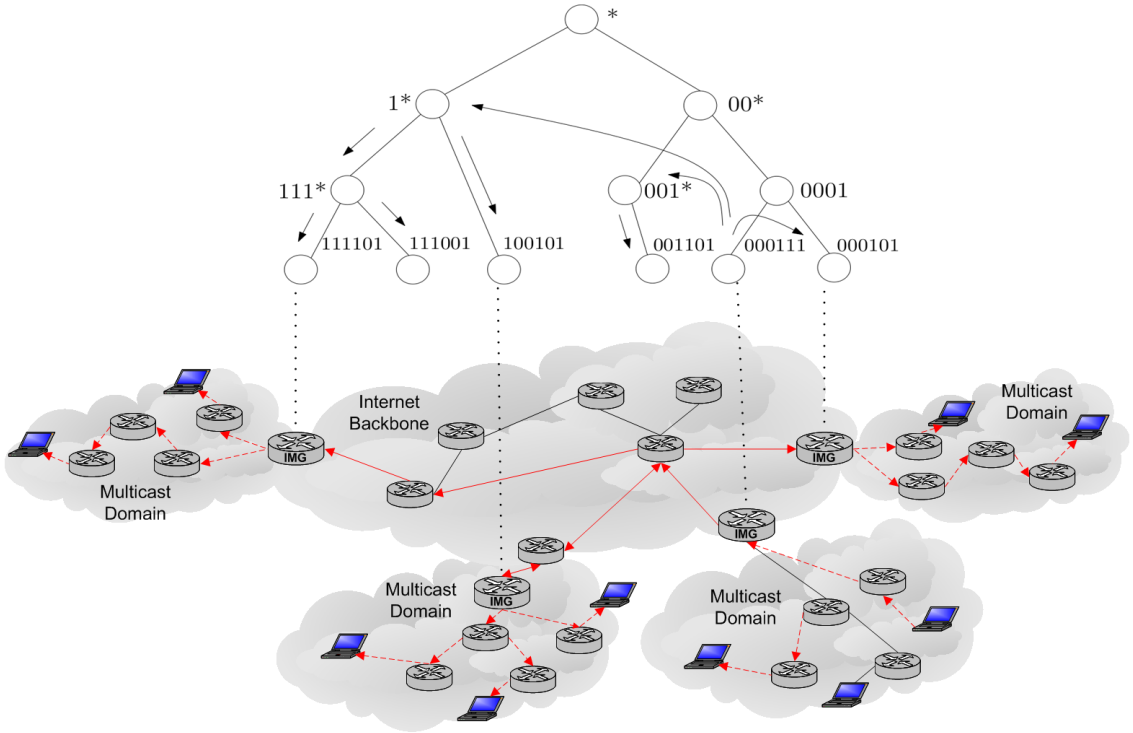
Mobile Nodes change location ...

The Rendezvous Problem

How can mutually unknown parties meet each other on the Internet (e.g., to retrieve content)?

- without central indexing (Google)
- without globally coherent knowledge base (BGP)
- without central rendezvous point (PIM)
- without (unbounded) Broadcast

Partial Flooding of Shared Virtual Tree



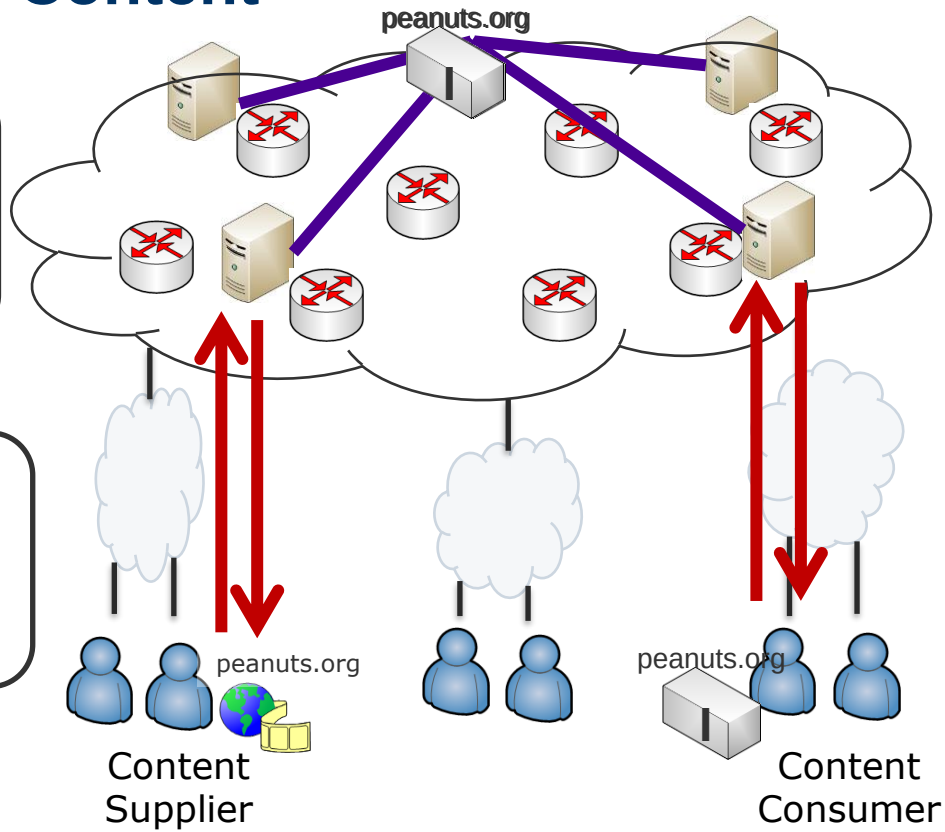
Future: Routing to Content

Core:

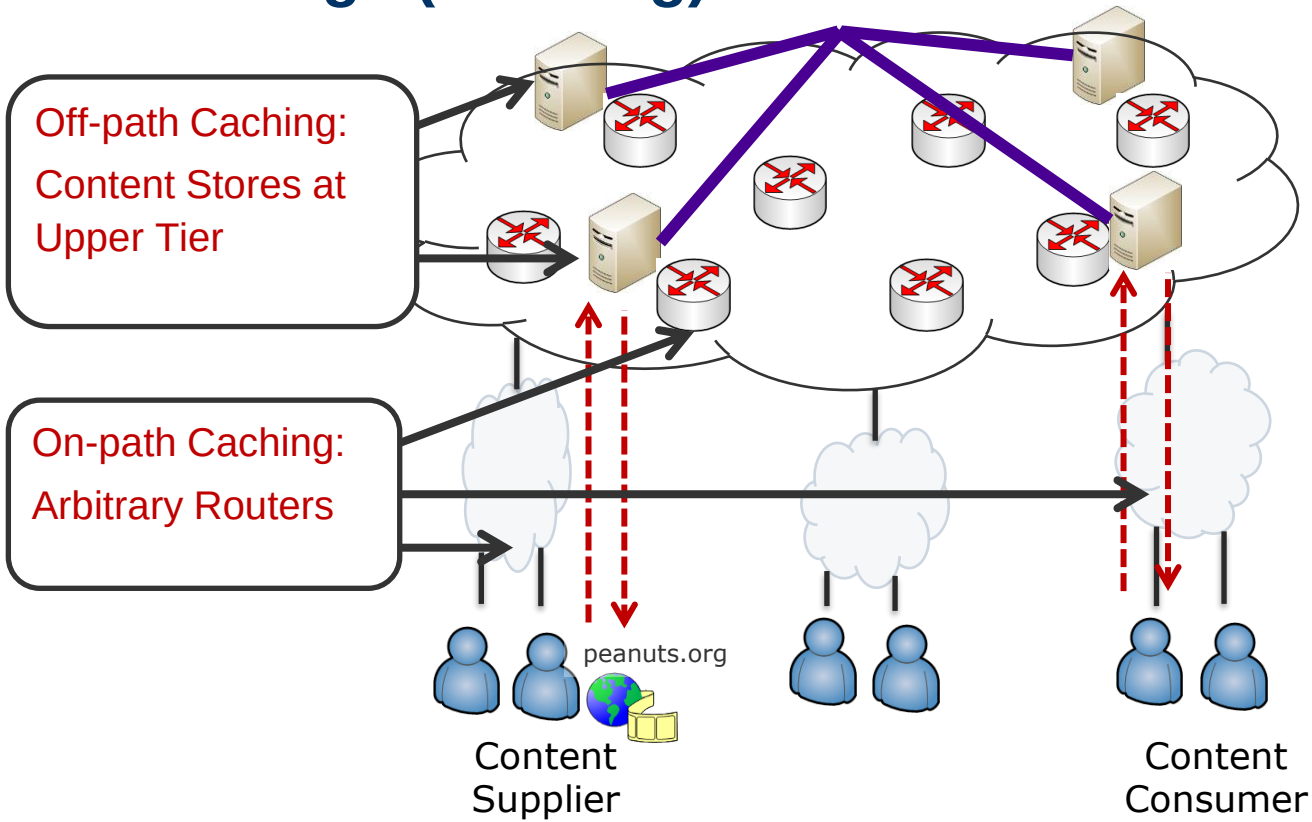
Bidirectional Shared Tree

Supplier:

Registers Name at Content Store



In-Network Storage (Caching)



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Introduction to

INTERNET OF THINGS

The IoT Edge

Massive deployment of networked controllers
- Mainly resource constrained
- Optimized for cost – not for quality
- Weakened communication UDP++
- Weak security: open ICS traffic
- High amplification for COAP + MQTT-SN

Heterogeneous deployment options in 5G
- Vertical slices
- Industrial/OEM private networks expected
- New major challenge for security and privacy: autonomous driving

Internet of Things

Very many tiny systems
- without user interface
- Machine-to-Machine communication
- Energy often *the* limitation
- Security challenges: identity and authenticity

Continuously emerging application areas
- Industry 4.0 & smart homes
- Distributed data sensing
- Autonomous driving
- Embedded intelligence …

Web of Things

Make applications interoperable

- Device management and integration
- Data transport
- Data organization
- Data encoding
- Data semantics

W3C and industry consortia compete about future solutions

Software & Security

- Software problems
  - Developer friendliness
  - Compatibility
  - Energy efficiency
  - Real-time support
- Security problems
  - Lightweight crypto
  - Infrastructureless authenticity
  - Secure communication
  - Privacy & data governance