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

Next NSM class

in Summer'25

"The Network
is the
Computer"

- John Gage

o Selected Aspects of Cyber-physical Systems

o Advanced Internet and IoT Technologies

o Real-time Systems

o Network Security and Measurement

o Protocol Engineering

o Distributed Adaptive Systems

Time schedule & assignments

Course hours: Wednesday 12:30-15:45

- 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 KW 22
→ 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 presented one paper + lab work successfully.

Project presentation = 1/3 of final grade		Final oral exam = 2/3 of final grade

You NEED to register online in MyHAW (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-2024/ait**
- 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
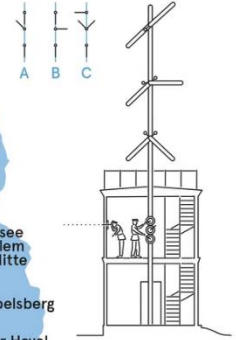
Introduction to

INTERNET TECHNOLOGIES
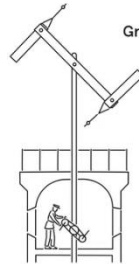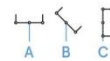
Networking is a long-standing desire

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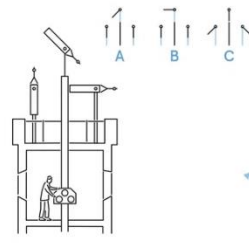
Hamburger optischer Telegraf

Berlin–Koblenz: Preußischer optischer Telegraf

Metz–Mainz: Optischer Telegraf nach C. Chappe

Netzabdeckung in der ersten Hälfte des 19. Jahrhunderts – die Linien optischer Telegrafen

# 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*

We change perspectives
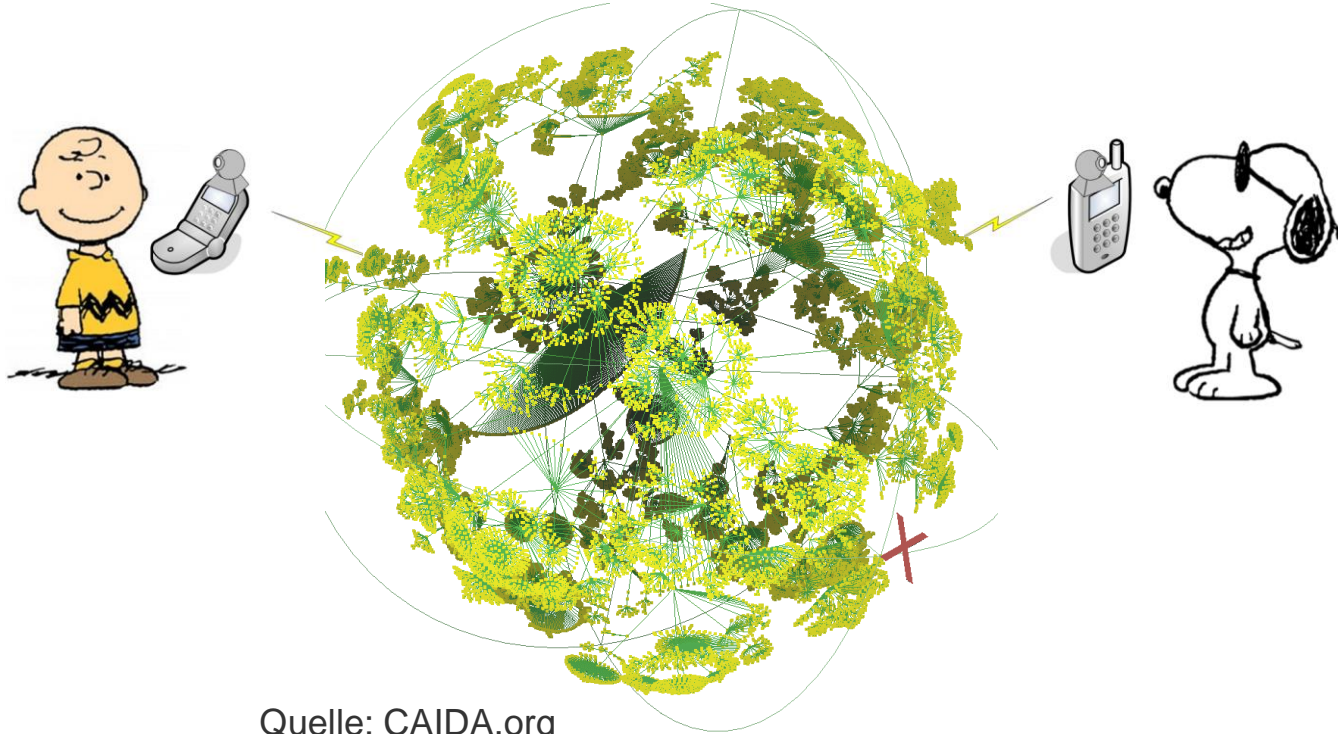
Quelle: CAIDA.org

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

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?
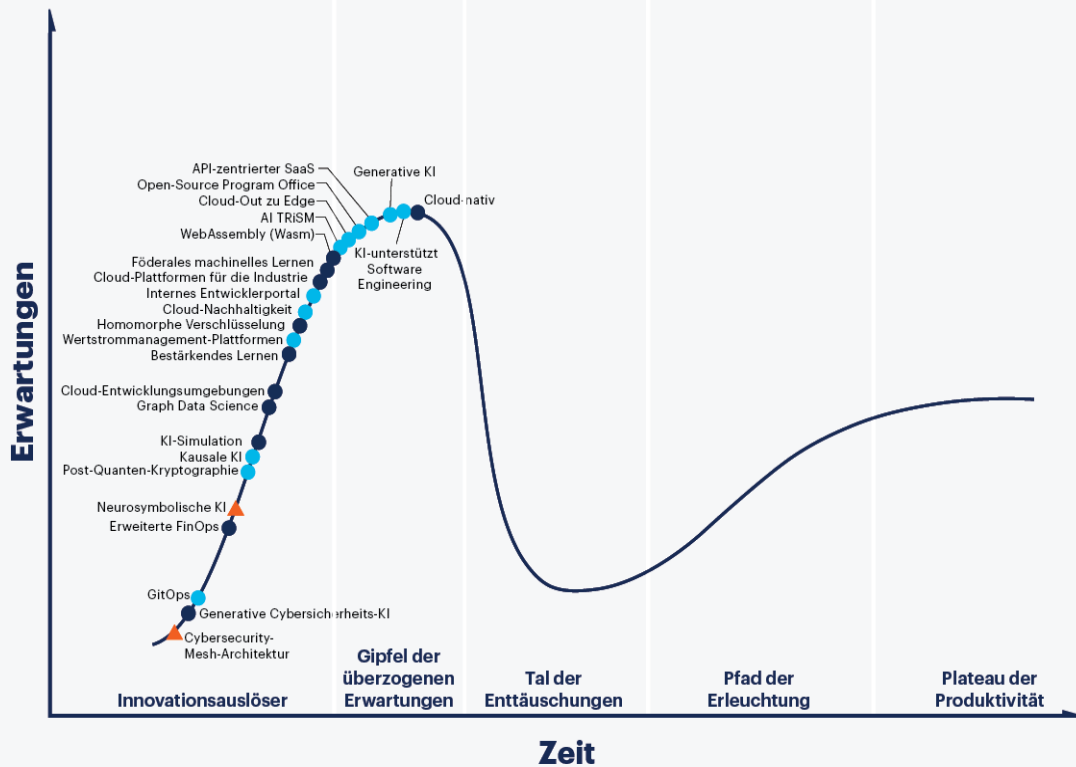
Networks are the backbone of Computing

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 für neue Technologien 2023

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
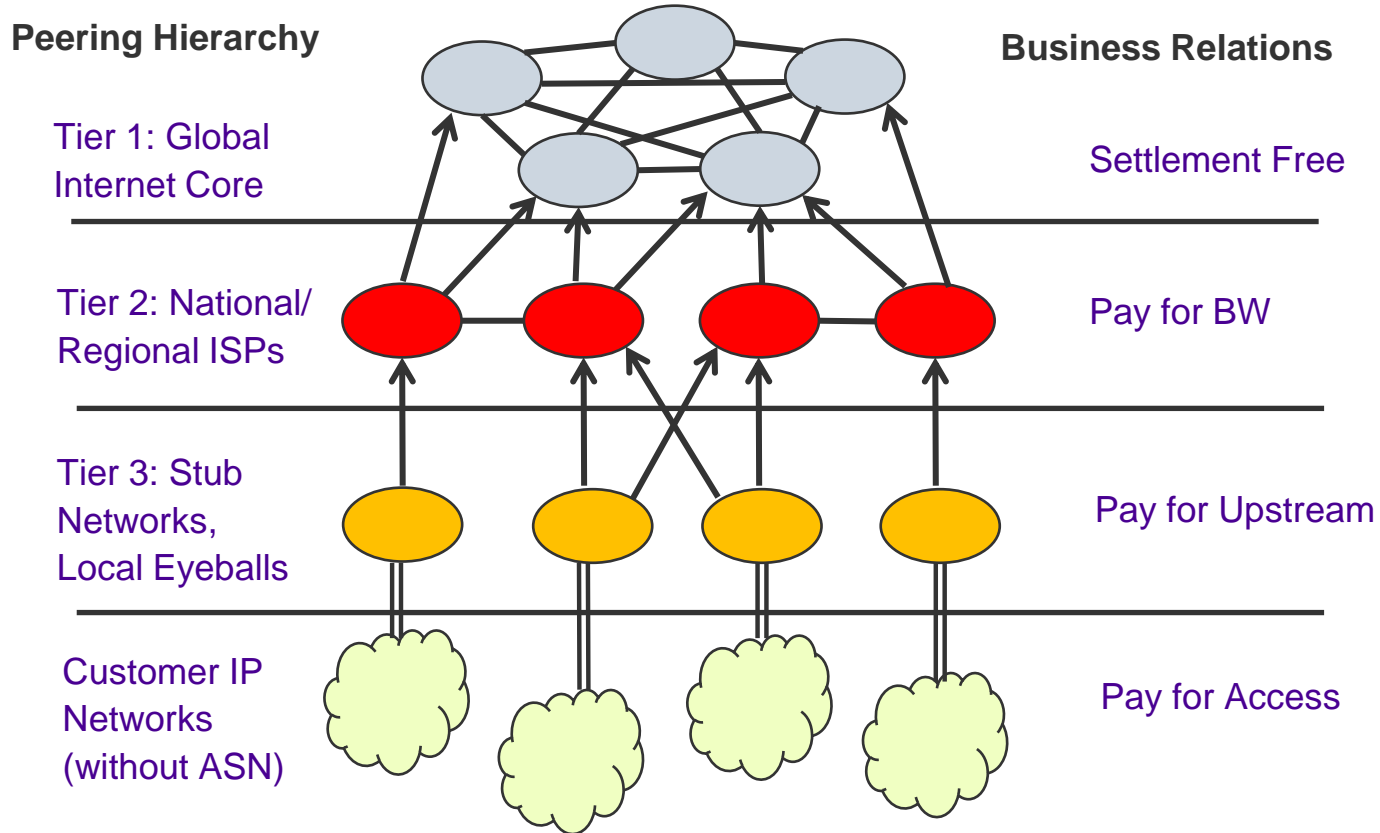
Business as a Problem for the Internet?
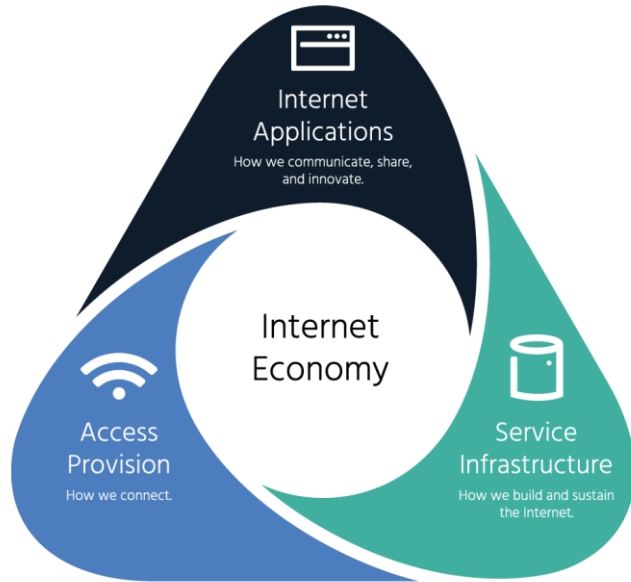
Source: ISOC Internet consolidation report 2019
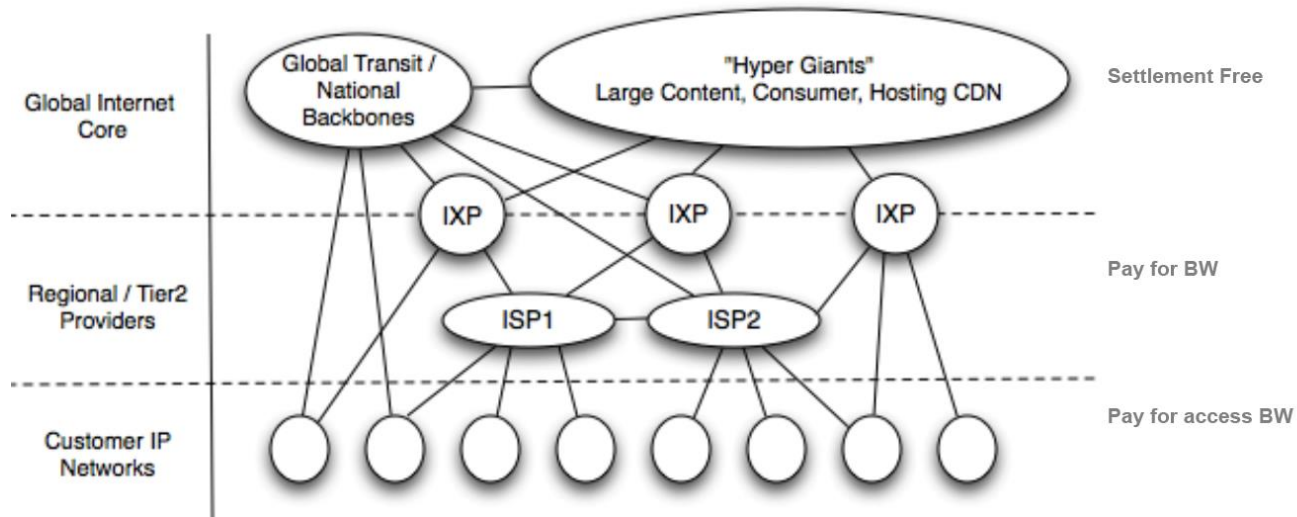
The Internet Ecosystem is changing

- 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

Peering Hierarchy

Tier 1: Global Internet Core

Tier 2: National/ Regional ISPs

Tier 3: Stub Networks, Local Eyeballs

Customer IP Networks (without ASN)

Business Relations

Settlement Free
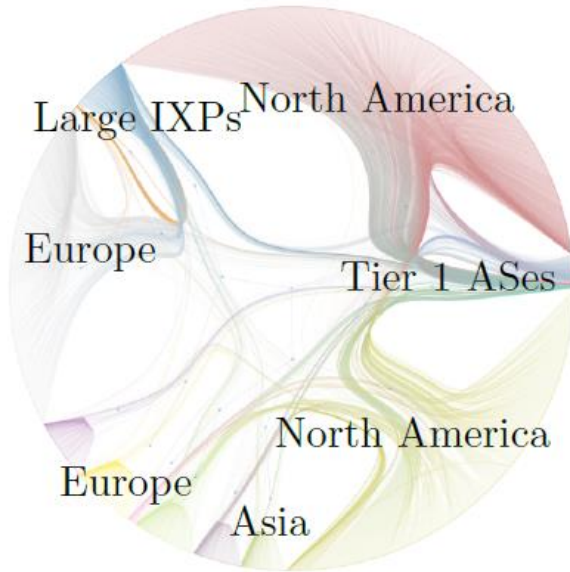
Pay for BW

Pay for Upstream

Pay for Access

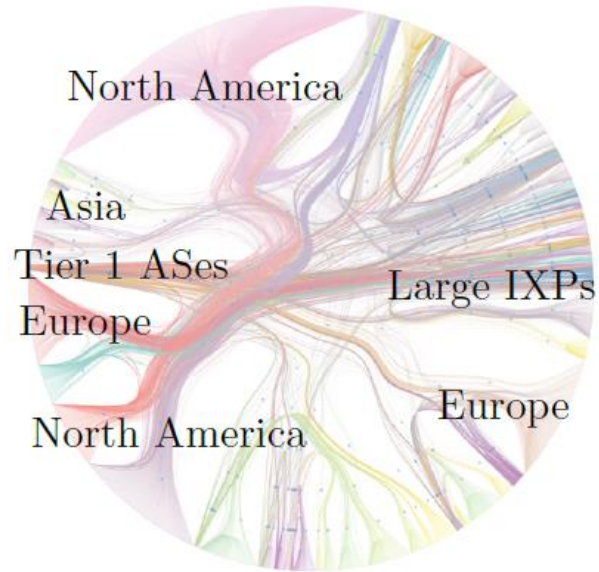# Flattening Internet Topology

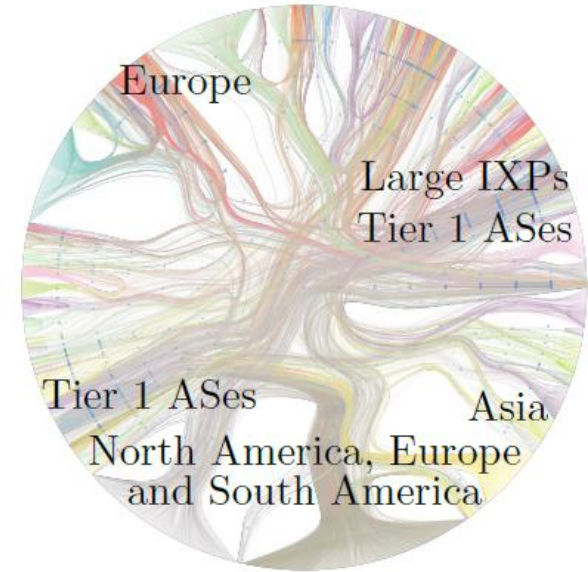Quelle: G. Labovitz, et al.: Internet Inter-Domain Traffic, SIGComm 2010

The Internet merges and grows together

(a) 2000

(b) 2010

(c) 2020

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

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

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

G 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)

N
MBURG

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

o Global ubiquity   o Mobility

o Service adaptivity   o Group communication

The Video Tsunami

Audio + Video on the Internet?

A long story:

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

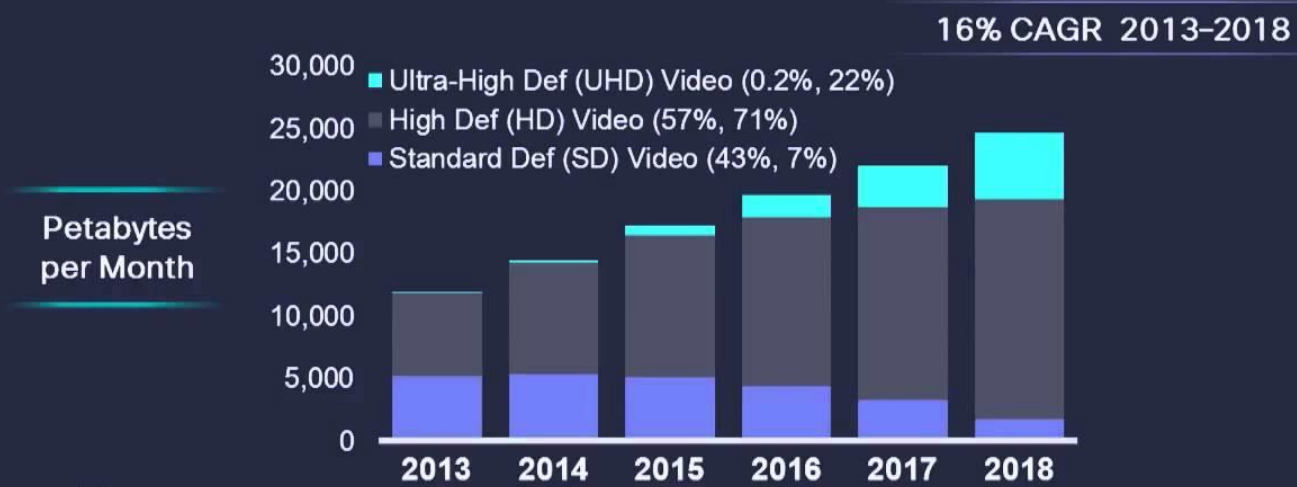1990 – Internet Stream Protocol II – IPv5 (RFC 1190)

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

Growing Definition of Global IP VOD
Ultra-HD IP VOD Will Account for 22% of VOD Traffic in 2018

16% CAGR 2013–2018

■ Ultra-High Def (UHD) Video (0.2%, 22%)
■ High Def (HD) Video (57%, 71%)
■ Standard Def (SD) Video (43%, 7%)

Petabytes per Month

* Figures (n) refer to 2013, 2018 traffic share
Source: Cisco VNI Global IP Traffic Forecast, 2013–2018
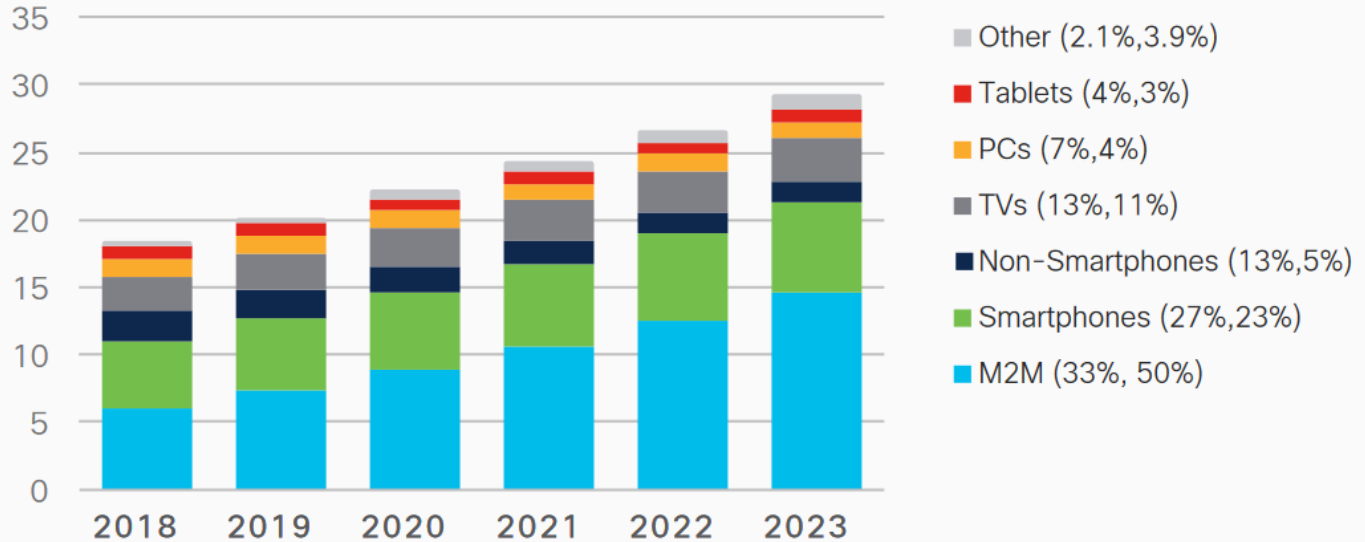© 2013-2014 Cisco and/or its affiliates. All rights reserved.

Cisco Confidential   5

Development of devices connected to the Internet

10% CAGR
2018–2023

Billions of Devices

Other (2.1%,3.9%)
Tablets (4%,3%)
PCs (7%,4%)
TVs (13%,11%)
Non-Smartphones (13%,5%)
Smartphones (27%,23%)
M2M (33%, 50%)

* 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:
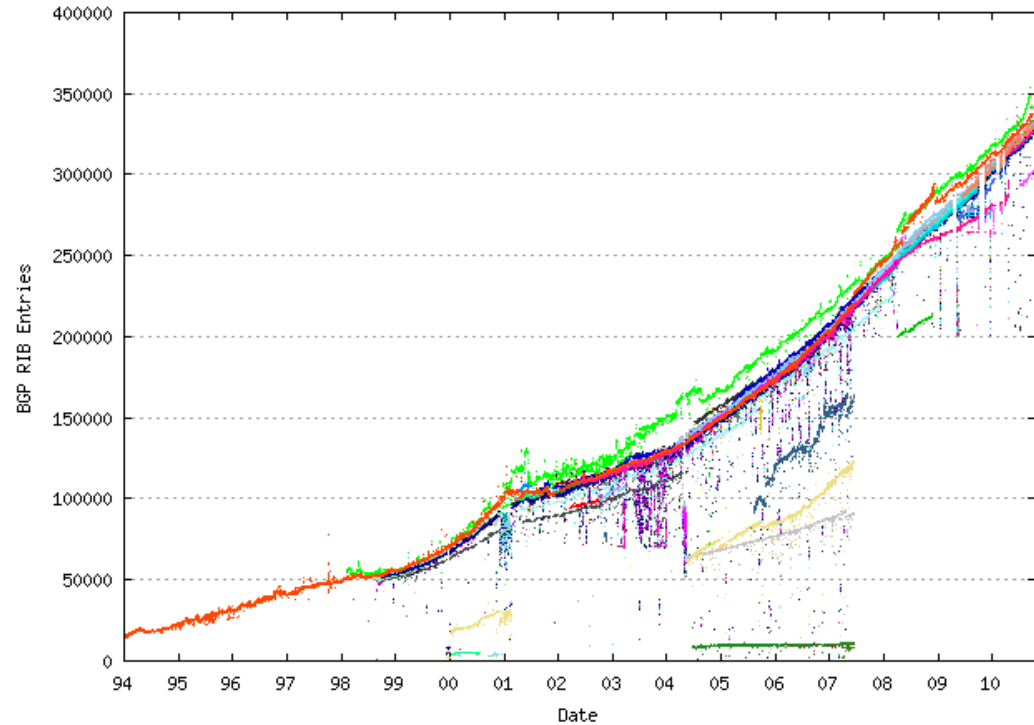
Addressing

Routing

Keep all Internet members reachable by a unique address.

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?)
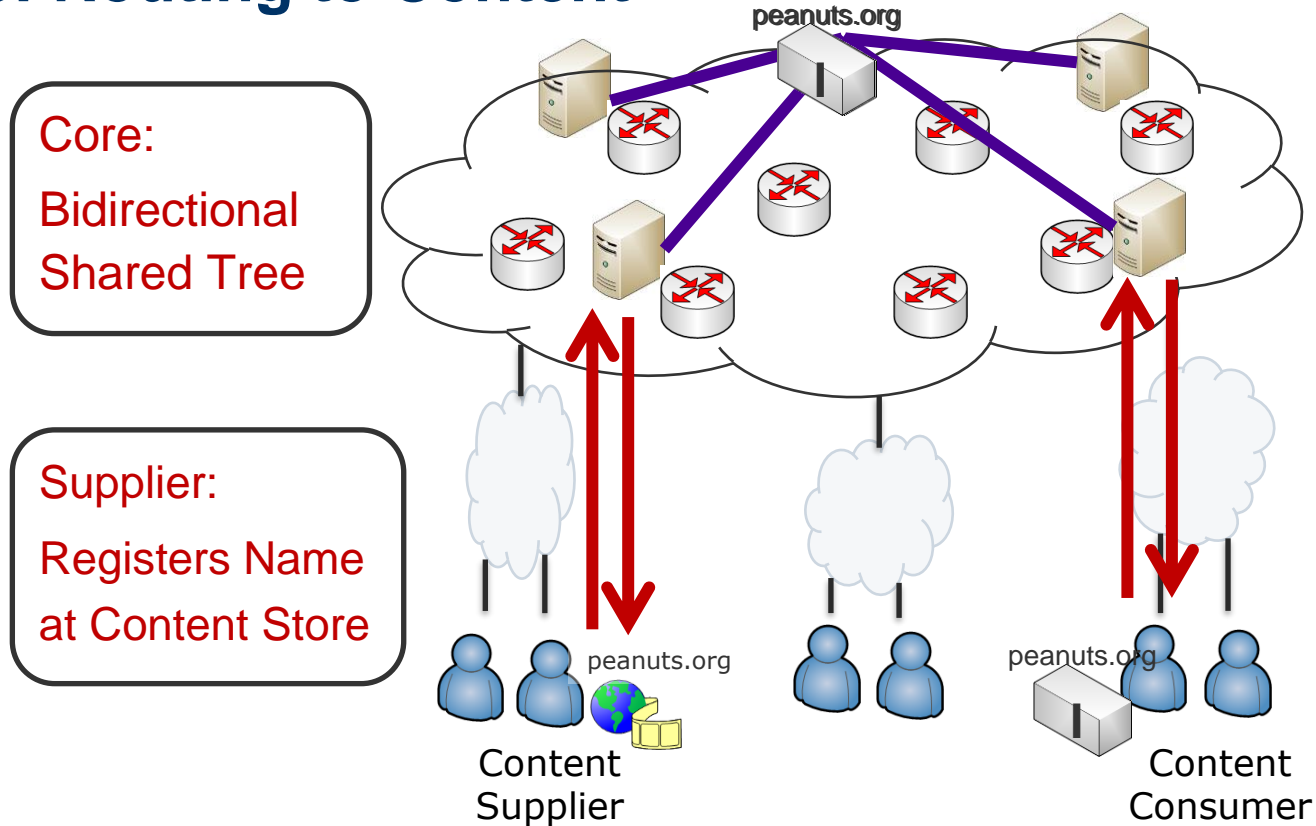- the location (where it is?)

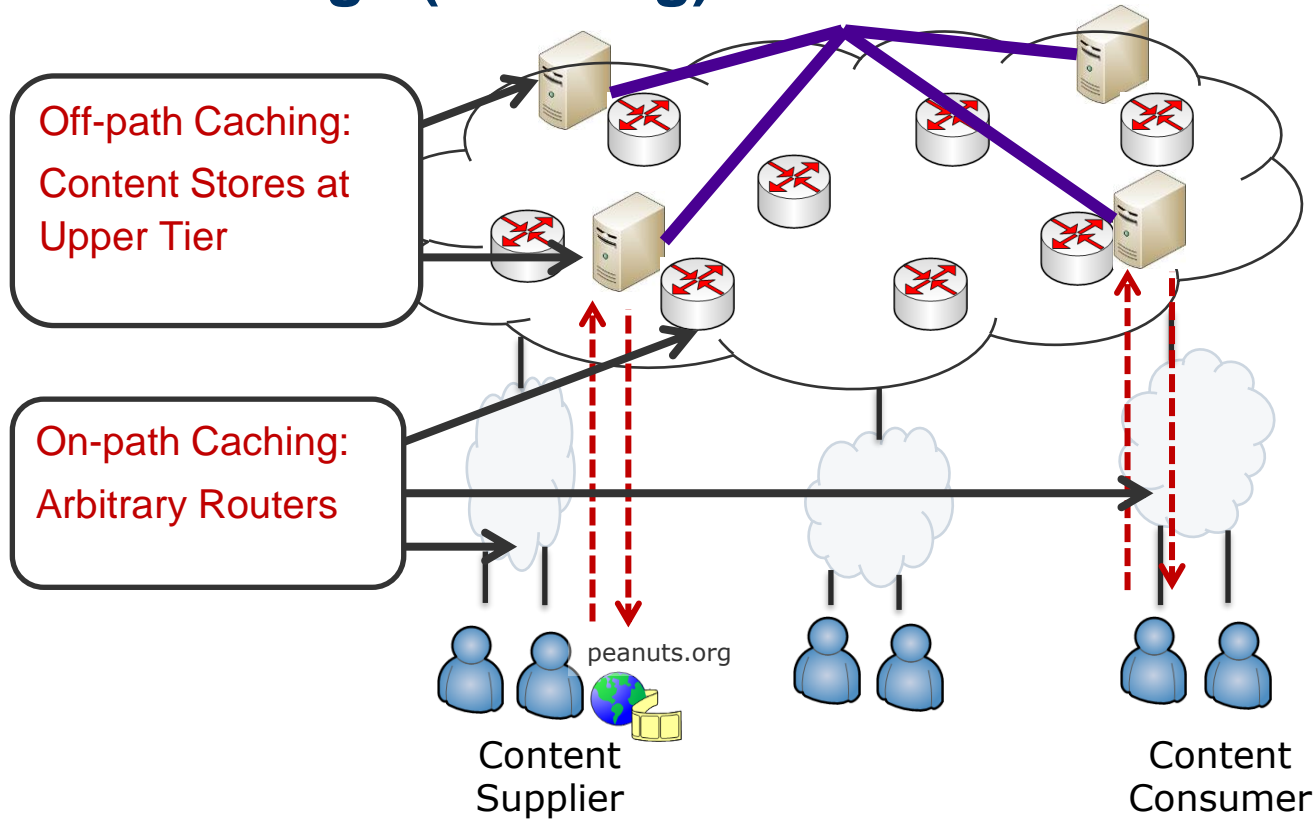Mobile Nodes change location ...

The Rendezvous Problem

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

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

Future: Routing to Content

Core:

Bidirectional Shared Tree

Supplier:

Registers Name at Content Store

peanuts.org

Content Supplier

peanuts.org

Content Consumer

In-Network Storage (Caching)

Off-path Caching:
Content Stores at
Upper Tier

On-path Caching:
Arbitrary Routers

peanuts.org

Content
Supplier

Content
Consumer

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

o Device management and integration

o Data transport

o Data organization

o Data encoding

o Data semantics

W3C and industry consortia compete about future solutions

You do need more than a cool technical solution ;)

A logo

You do need more than a cool technical solution ;)

The friendly operating system for the Internet of Things.

A logo

A catchphrase

You do need more than a cool technical solution ;)

The friendly operating system for the Internet of Things.
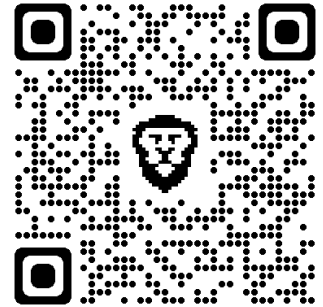
A logo   A catchphrase   T-shirts

Try it!

If you don't believe in practice,
RIOT serves as sound platform for IoT networking research.
[ACM CoNEXT'21&23, ACM/IEEE IPSN'22, EWSN '22&'23,
ACM TECS 20(5s)&20(3), ACM SenSys'22, IEEE ComMag'24 …]

https://www.riot-os.org