Network, Traffic and Quality Management for Internet Services

Overview of Organisation Aspects

Brief Introduction of Core Topics (QoS: Quality of Service)

- QoS – Demands of IP Services
- QoS – Architecture in IP Networks (DiffServ, IntServ)
- Routing & Infrastructure of ISPs and in the global Internet
- Content Delivery via CDN/P2P Overlays, Clouds
  from Network, Service, Content Provider & User Perspective
- IP Traffic Mix: Components, Growth, Variability
- Measurement, Monitoring & Network/Traffic Management

Network-, Traffic- & Quality-Mgnt. for Internet Services

Persons

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This course runs

2 hours on Monday 8:55; in each summer term; with small exercises part

Oral exams & consultation hours: t.b.d. at flexible dates on demand

Material

Slides, several script parts, exercises with solutions
are made available via TUCAN

Overview: Slide Sets ↔ Script Parts

Slide Sets:

1. Overview
2. Quality-of-Service (QoS): User Demands; IP Service Categories
   → **Material-1-TCP-IP-QoS & Material-0-English-Collection**
3. IP Routing Methods: OSPF, BGP, incl. Failure Resilience
   → **Material-2-Routing-OSPF-BGP**
4. QoS-Support in IP-Netzen: IntServ, DiffServ, (TCP Control)
   → **Material-1-TCP-IP-QoS**
5. Multiprotocol Label Switching (MPLS): Traffic & Network Management
   → **Material-1-TCP-IP-QoS**
6. Overlays for Content Delivery on the Internet
   → **Material-3-Internet-Content-Delivery (CDN/P2P)**
7. Measurement & Statistics for Dimensionierung, IP Topology Upgrading
   → **Material-3-IP-CDN; Material-4-Network-Dimensioning-Planning**

Literature

Books: currently no good fitting book is known for this course

- Links to literature on special topics are given in slides & script parts

Journals with related survey topics can be found at

- IEEE: - Tutorials & Surveys, - Internet Computing ,
  - Communications Magazine, - Networks, etc.

- at other publishers, e.g.
  - Computer Networks/Communications (Elsevier / Wiley etc.)

- Home-Pages of Standardizaiton Bodies & Companies can partly help
  → Slide on Standardization Bodies
  in Slide Set QoS-03
  including: Internet Engineering Task Force (IETF) <www.ietf.org>

Topics on IP & QoS Support

- IP (Internet Protocol)
  Routing & Addressing
- Routing Methods
  Global: BGP
  Lokal: OSPF, IS-IS
  Shortest Path Routing (SPF)
  Traffic Engineering (TE)
  Failure Resilience
- (TCP Transmission Control Prot.
  Flow and Error Control
  Sliding Window Mechanism
  Fairness, Stability)

QoS Architecture:

- Integrated Services (IntServ)
  RSVP: Resource Reservation Prot.
- Differentiated Services
  Traffic Classes; Prioritization
- Multiprotocol Label Switching
  (MPLS): Convergence of:
  Routing ⇦⇨ Switching
  QoS: IntServ ⇦⇨ DiffServ
  GMPLS: IP ⇦⇨ Optical Net.
  \+ Path Control, Monitoring,
  Traffic Engineering

Topics on IP Traffic & Network Management

- Overlays for Content Delivery on the Internet:
  - Content Delivery Networks
  - Peer-to-Peer Networks
  - Caching

- ISP Network Management for Breitband Internet Access:
  - Traffic Measurement, Statistics & Management
  - Variability in Traffic Profiles & Impact on QoS
  - Application Mix & QoS Support

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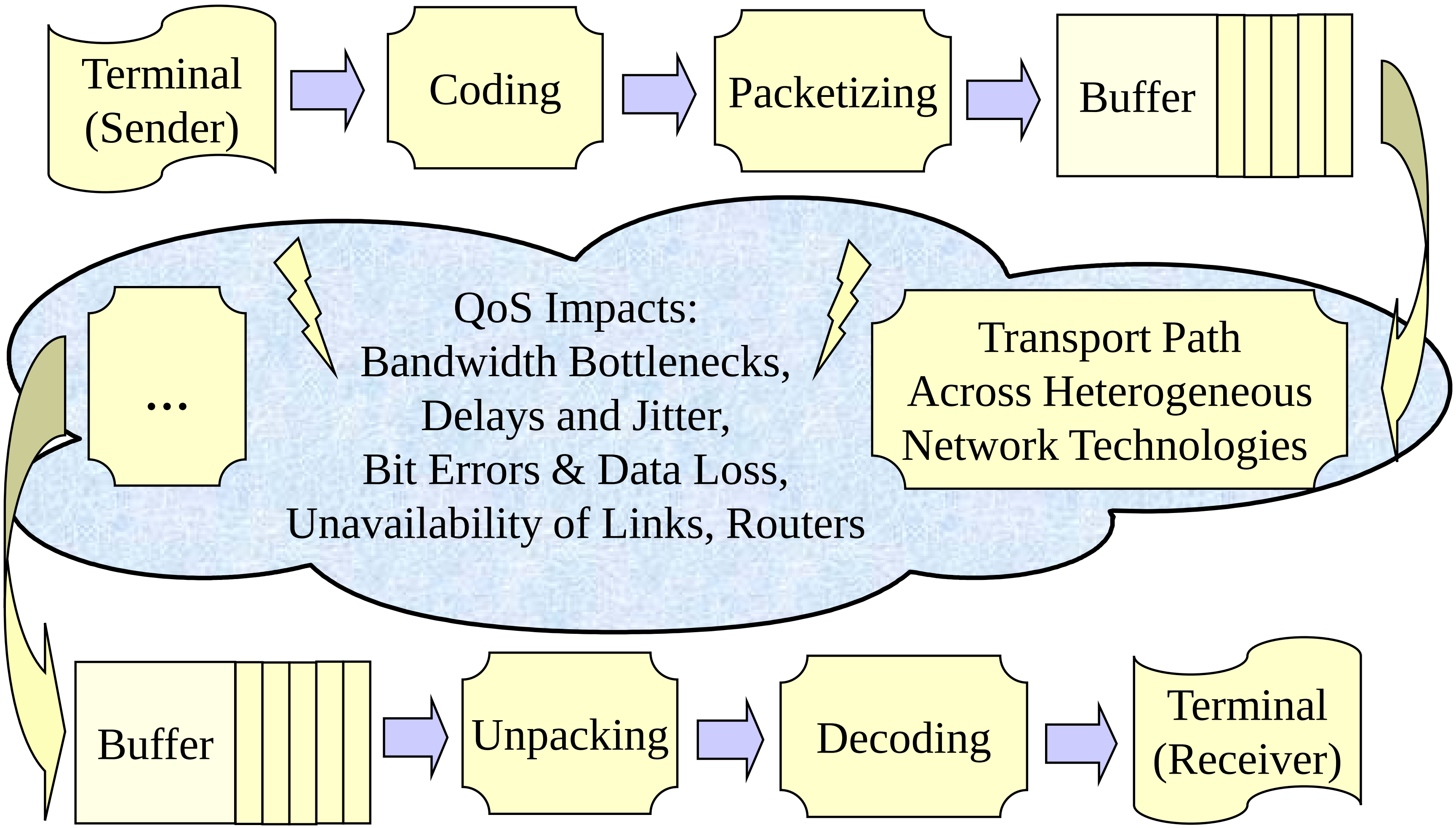
Services in Communication Networks

since		since		since	
1847	Telegraph	1980	Internet, Ethernet	2000	Peer-to-Peer-Netw.
1877	Telephone		Kabel TV		Online Games,
1900	Wireless Voice		E-Mail		E-Busi., E-Learn...
	Transmission		Telemetrie,		Social Networks
1920	Broadcasting, TV		Remote Control		
1930	Telefax, Telex		GSM Mobile Net.		UMTS, LTE,
1970	Digital Channels		Video Conf.		Mobile Ad Hoc,
	Satellite Channels				Sensor Networks
	Mobile Phones	1990	ISDN		Fixed-Mobile &
	Electronic		WWW		IP-TV-VoD
	Data Exchange,		Multimedia		Convergence
	Computer		Applications	2015	5G, Clouds, CDNs
	Networks		Intranets, VPNs		Internet of Things

Data Transfer Chain Across Telecommunication Networks & QoS Impacts



Service-,Traffic- & QoS-Classes: Categories & Demand Profiles

Service / Traffic Classes	Conversational	Streaming	Interactive	Background
Applications	Voice Calls, Video Conferencing Online Gaming	Video / audio on demand, IP-TV	Web browsing, E-Commerce, E-Learning etc.	File Transfers, Downloads, P2P, E-Mail, SMS, …
Communication-Traffic Pattern	Human-to-Human Bidirectional Partly Multicast	Server → Human >90% Downstream Uni/Multi/Broadcast	Human ↔ Server Query/Response Pattern	Data transfers without human interaction
QoS Parameters: 1. Delay	< 0.1s: excellent >0.25s: inappropriate	Time sequence of data to be preserved	< 0.5s: excellent >4s: inappropriate	Not critical
2. Failure Rate	Tolerance up to a few % bit/packet errors		No failures in end-to-end transfers	
3. Bandwidth	Low & high data volume demands in each class (e.g. voice ↔ video)			
Source: UMTS Standardization by ETSI/3GPP (TS 27.107 V3.9.0, 2002)				

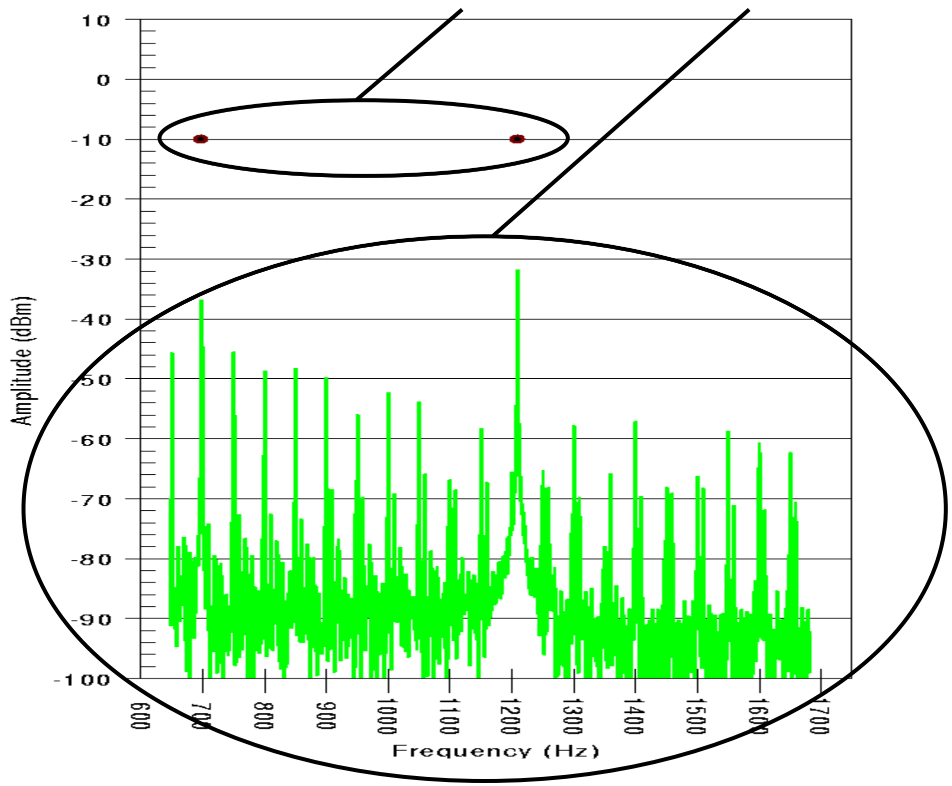
Subjektive & Objektive Voice Quality Measurement

Subjektive Methods are based on individual user experience (MOS*-Scale)

Objektive Methods are based on automated measmt. tools

- Impairments are evaluated (Signal ÷ Noise ratio, delay, jitter)
- A User Experience Model has been standardized to evaluate voice quality depending on impariments

Signal at Sender ↔ Receiver



Example: Spectrum analysis of a signal @ 700 & 1200 Hz with fading & superposed noise on the received side as part of a MOS analysis

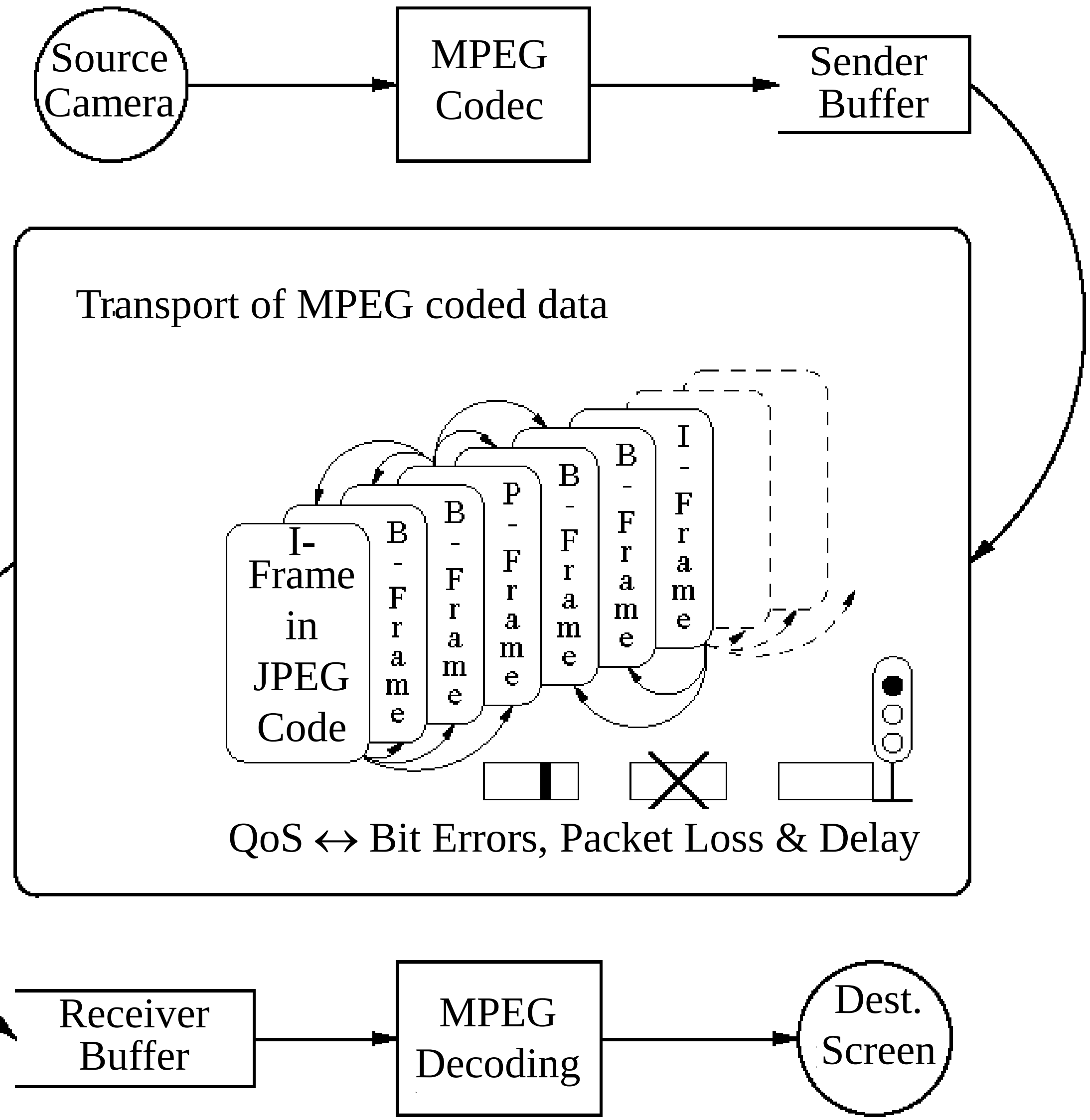
*MOS: Mean Opinion Score

ISO/IEC JTC1/SC29 WG11
MPEG
MOVING PICTURE EXPERTS GROUP

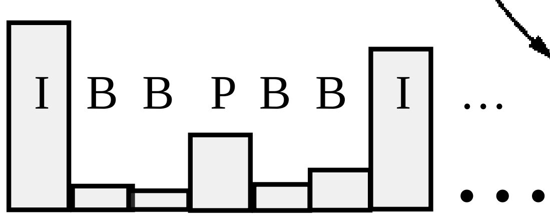
MPEG-Video-Transfers:

structured into Groups of Pictures (GoP) and Scenes

<www.mpeg.org>



Size of MPEG Frames

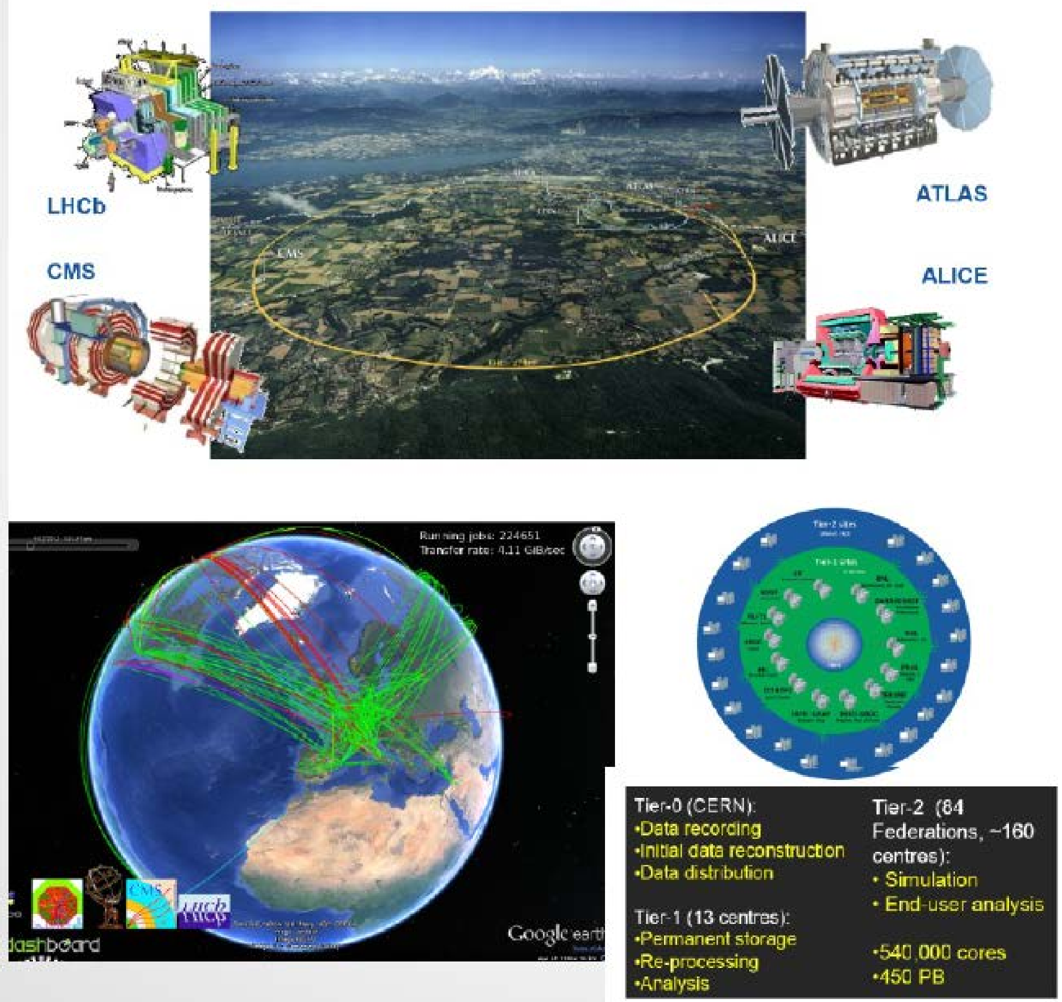


Extreme Demands, e.g., in Future 5G Networks
Source: Next Generation Mobile Networks NGMN White Paper (March 2015)

Table 1: User Experience Requirements

Use case category	User Experienced Data Rate	E2E Latency	Mobility
Broadband access in dense areas	DL: 300 Mbps UL: 50 Mbps	10 ms	On demand, 0-100 km/h
Indoor ultra-high broadband access	DL: 1 Gbps, UL: 500 Mbps	10 ms	Pedestrian
Broadband access in a crowd	DL: 25 Mbps UL: 50 Mbps	10 ms	Pedestrian
50+ Mbps everywhere	DL: 50 Mbps UL: 25 Mbps	10 ms	0-120 km/h
Mobile broadband in vehicles (cars, trains)	DL: 50 Mbps UL: 25 Mbps	10 ms	On demand, up to 500 km/h
Airplanes connectivity	DL: 15 Mbps per user UL: 7.5 Mbps per user	10 ms	Up to 1000 km/h
Ultra-low latency	DL: 50 Mbps UL: 25 Mbps	<1 ms	Pedestrian
Resilience and traffic surge	DL: 0.1-1 Mbps UL: 0.1-1 Mbps	Regular communication: not critical	0-120 km/h
Ultra-high reliability & Ultra-low latency	DL: From 50 kbps to 10 Mbps; UL: From a few bps to 10 Mbps	1 ms	on demand: 0-500 km/h

CERN: High Energy Physics Workload in Distributed Cloud



Run 1/LS 1

~1 PB/sec

25-30 PB/year

0.5 M cores

0.5 EB storage

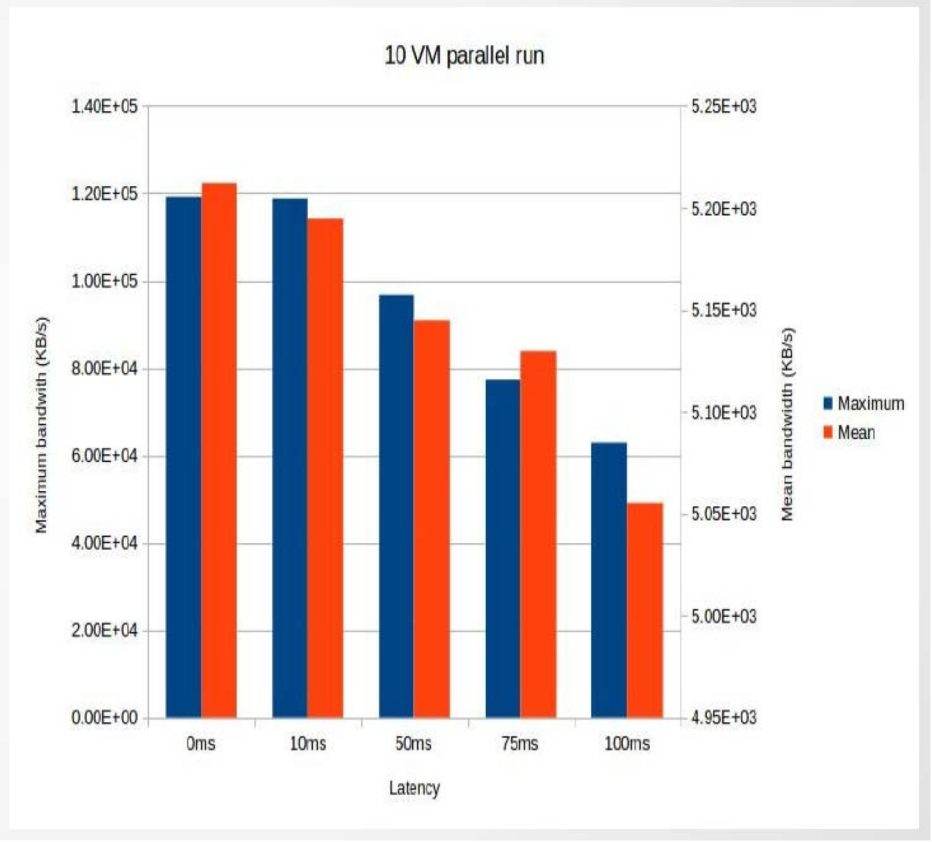
2 M jobs/day

24/7 operations

CERN: High Energy Physics Workload in Distributed Cloud <home.cern>, <opennebula.org>

Data Throughput is affected already by small delays:

CERN cloud has massive computing demands with high data volumes required per computation job



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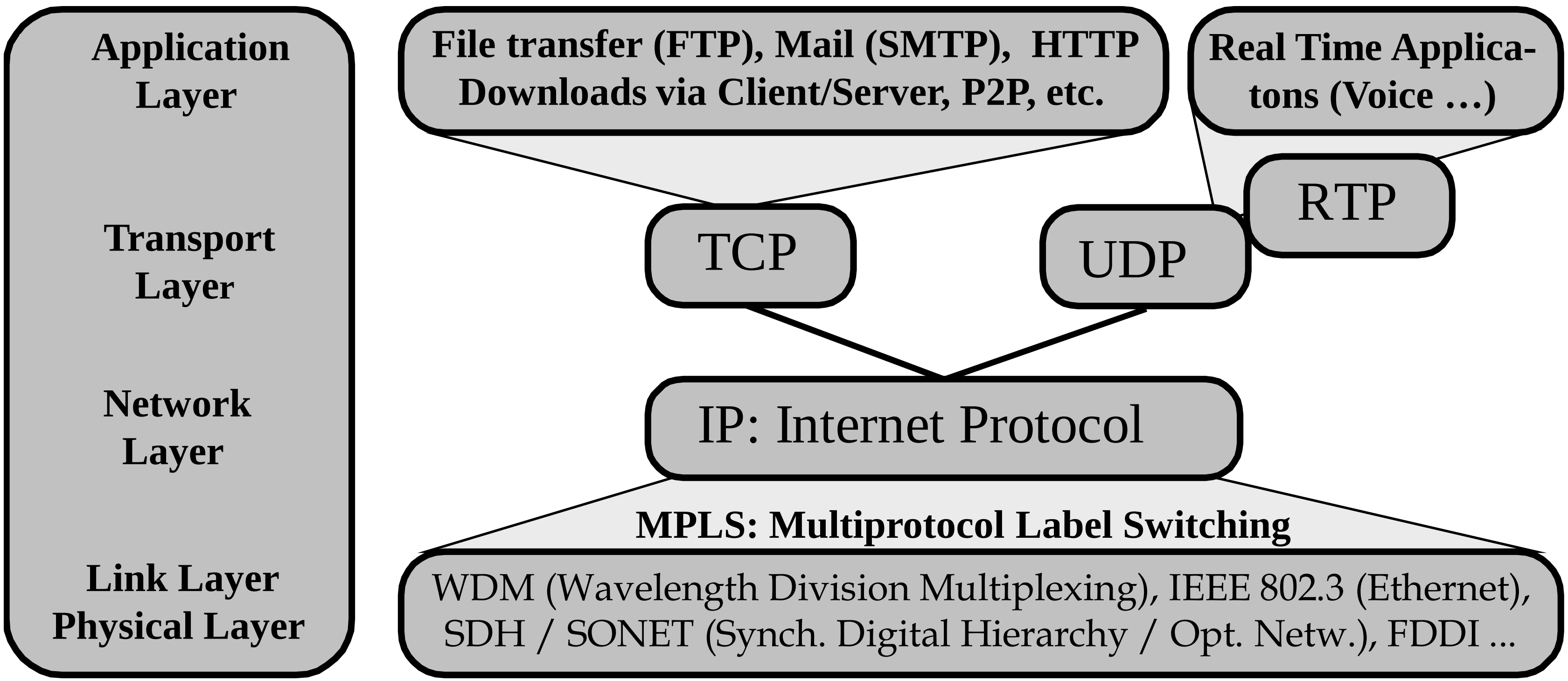
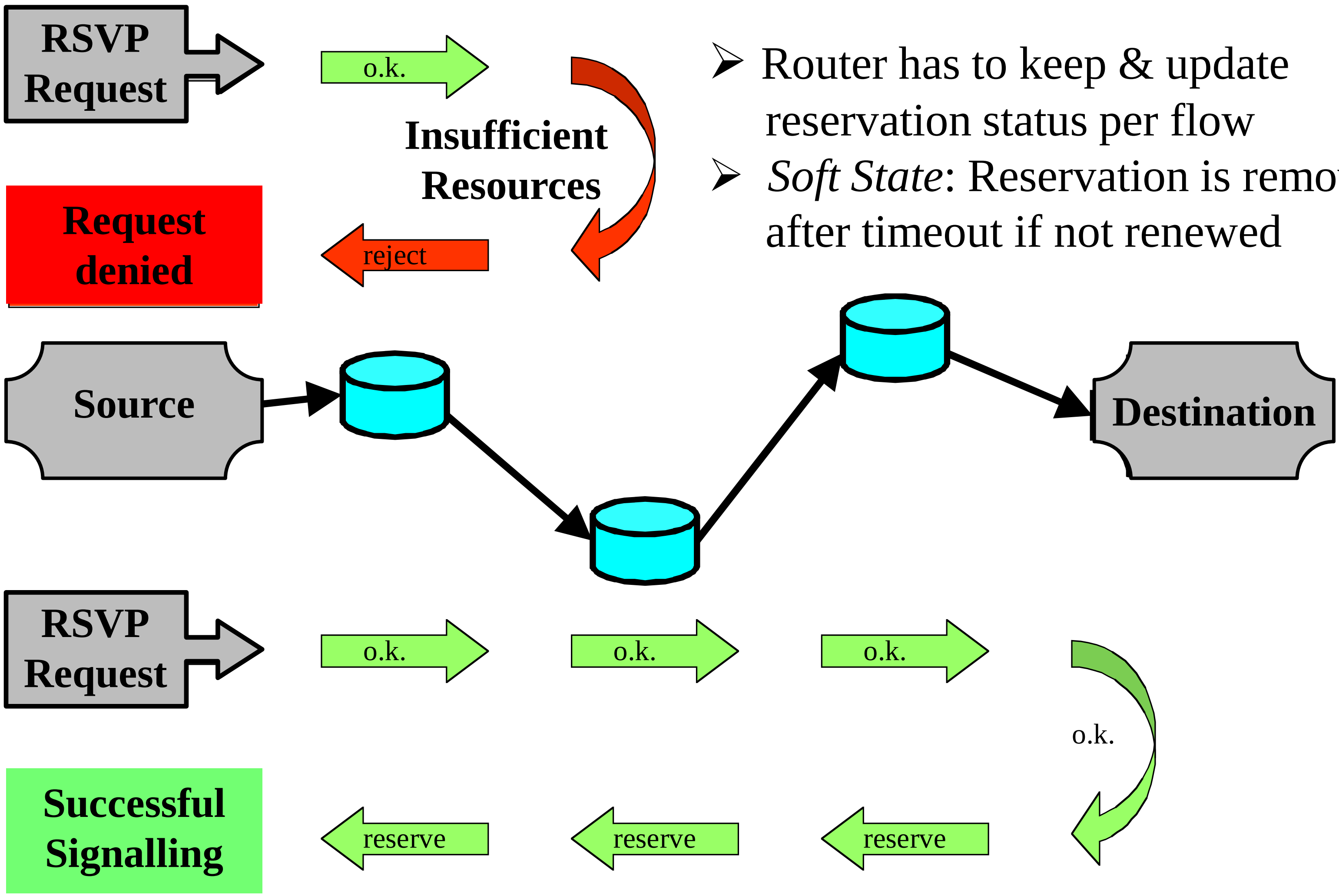
Protokol Layers in TCP/IP Networks



Basic Interent Transport Protocols:

TCP : Transmission Control P.	**RFC 793 (1981)**
UDP: User Datagram P.	**RFC 768 (1980)**
RTP: Transport P. for Real-Time Applications	**RFC 3550 (2003)**

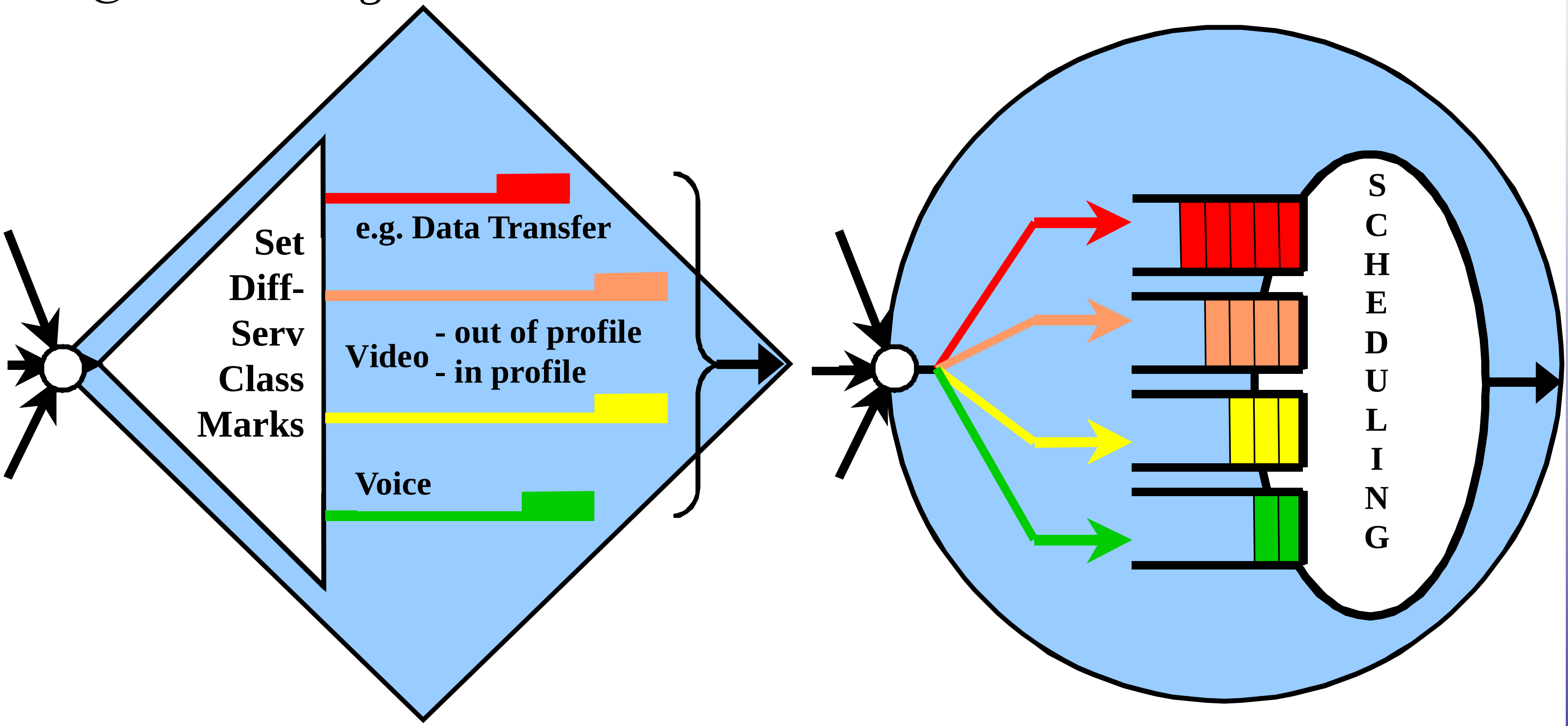
Integrated Services with RSVP: Signalling & Resource Reservation



- Router has to keep & update reservation status per flow
- *Soft State*: Reservation is removed after timeout if not renewed

IP-QoS: Differentiated Services (DiffServ)

@ DiffServ Ingress/Border Routers @ Routers within a DiffServ Domain



Traffic is classified
at the ingress to a DiffServ domain
with ToS/DS mark in the IP header

Differentiated routing behaviour per class
- Prioritization - Packet drop
- Bandwidth per class, packet scheduling

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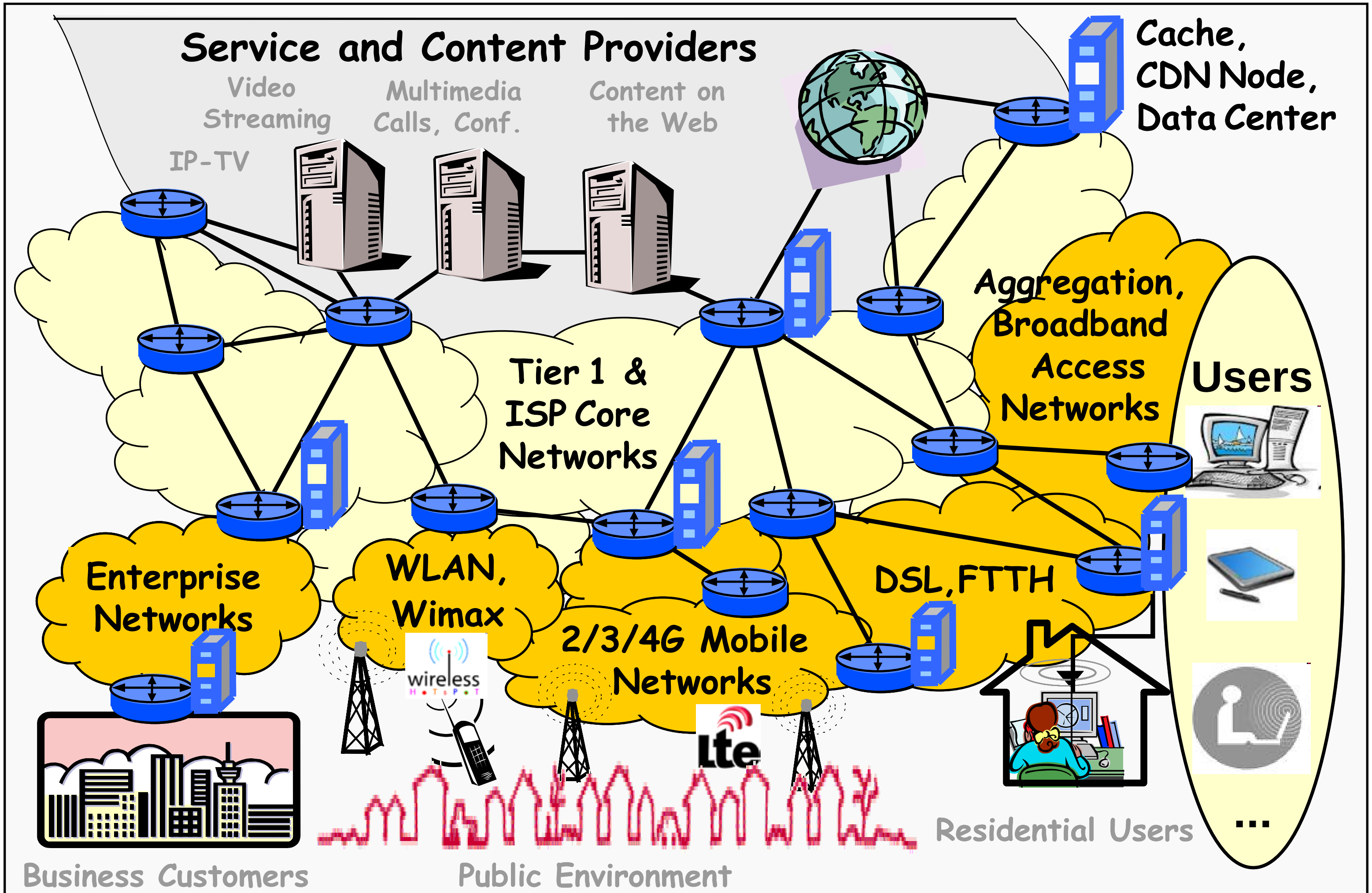
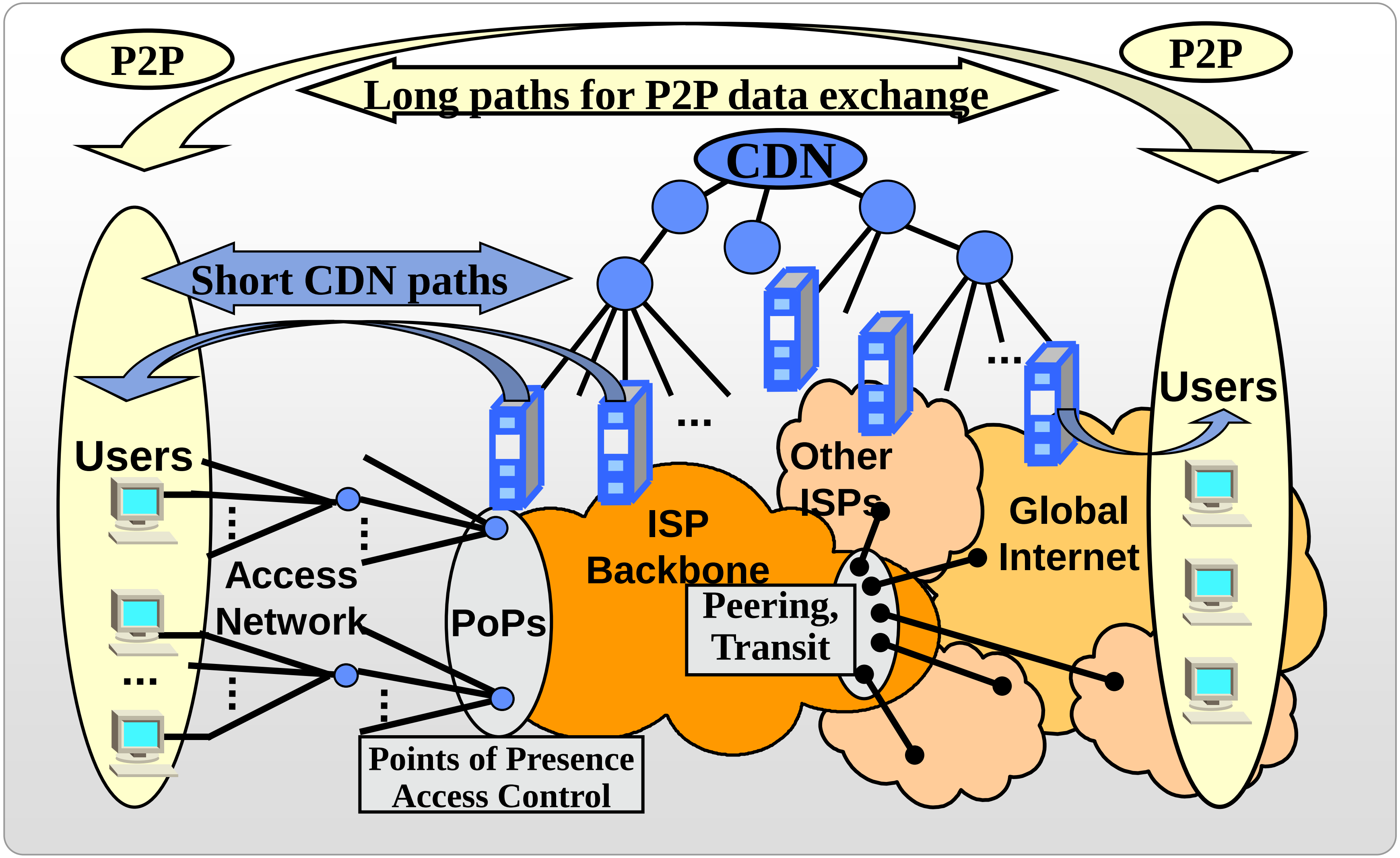
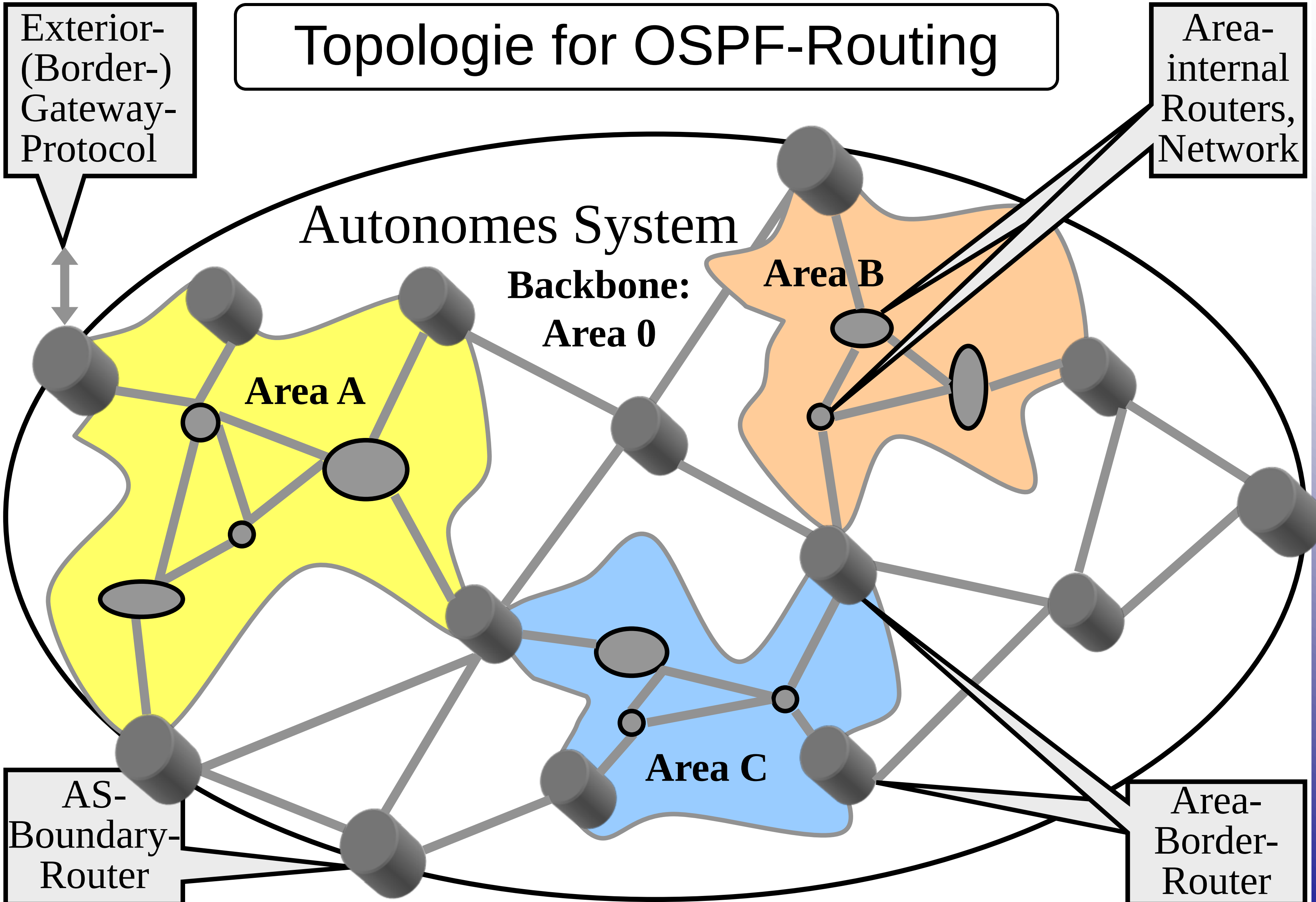
Global IP Network Infrastructure

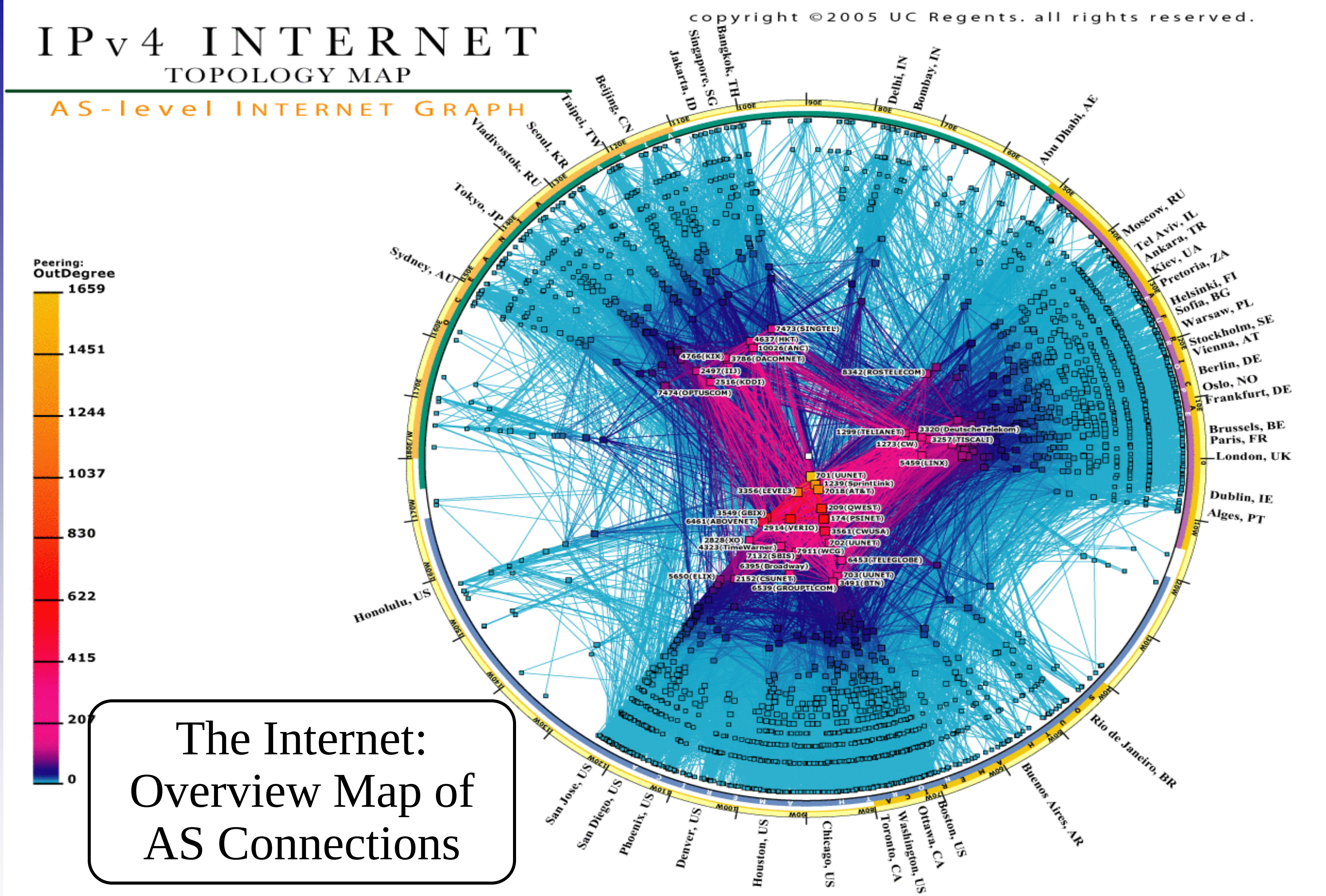


Content Distribution: CDN ↔ Peer-to-Peer Overlays



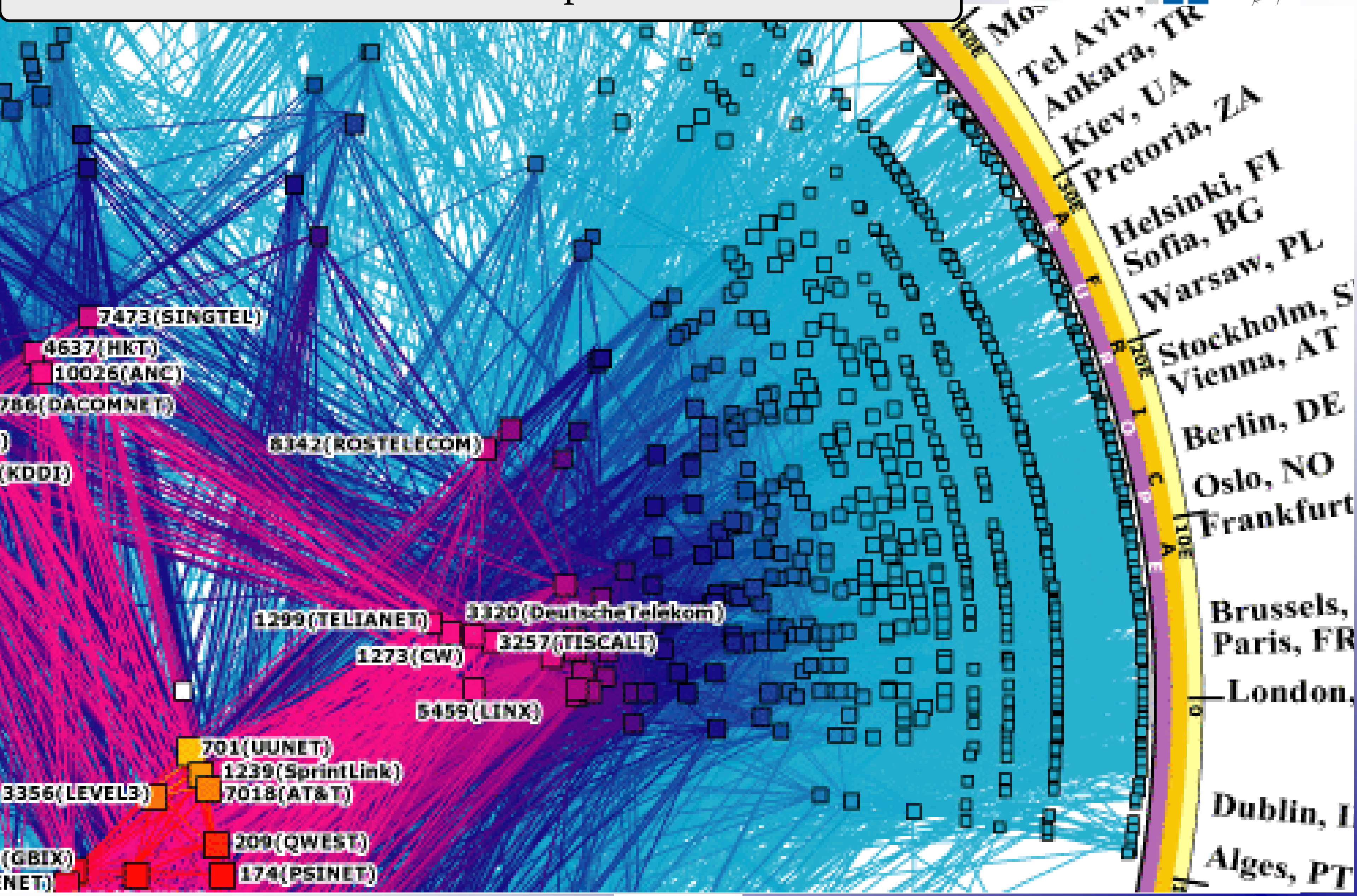
Topologie for OSPF-Routing



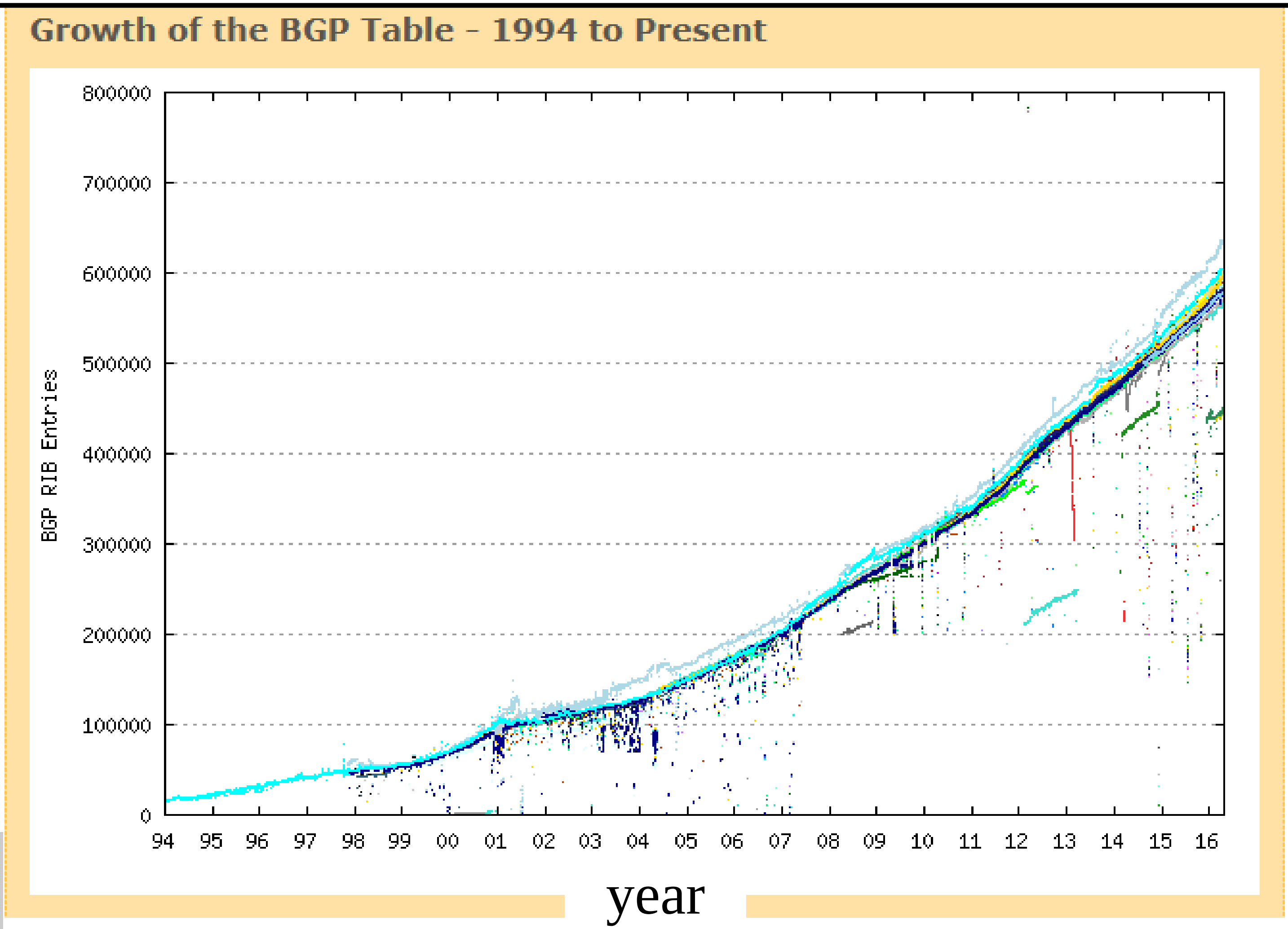


The Internet:
Overview Map of
AS Connections

Internet Connections in Europe and central ASes



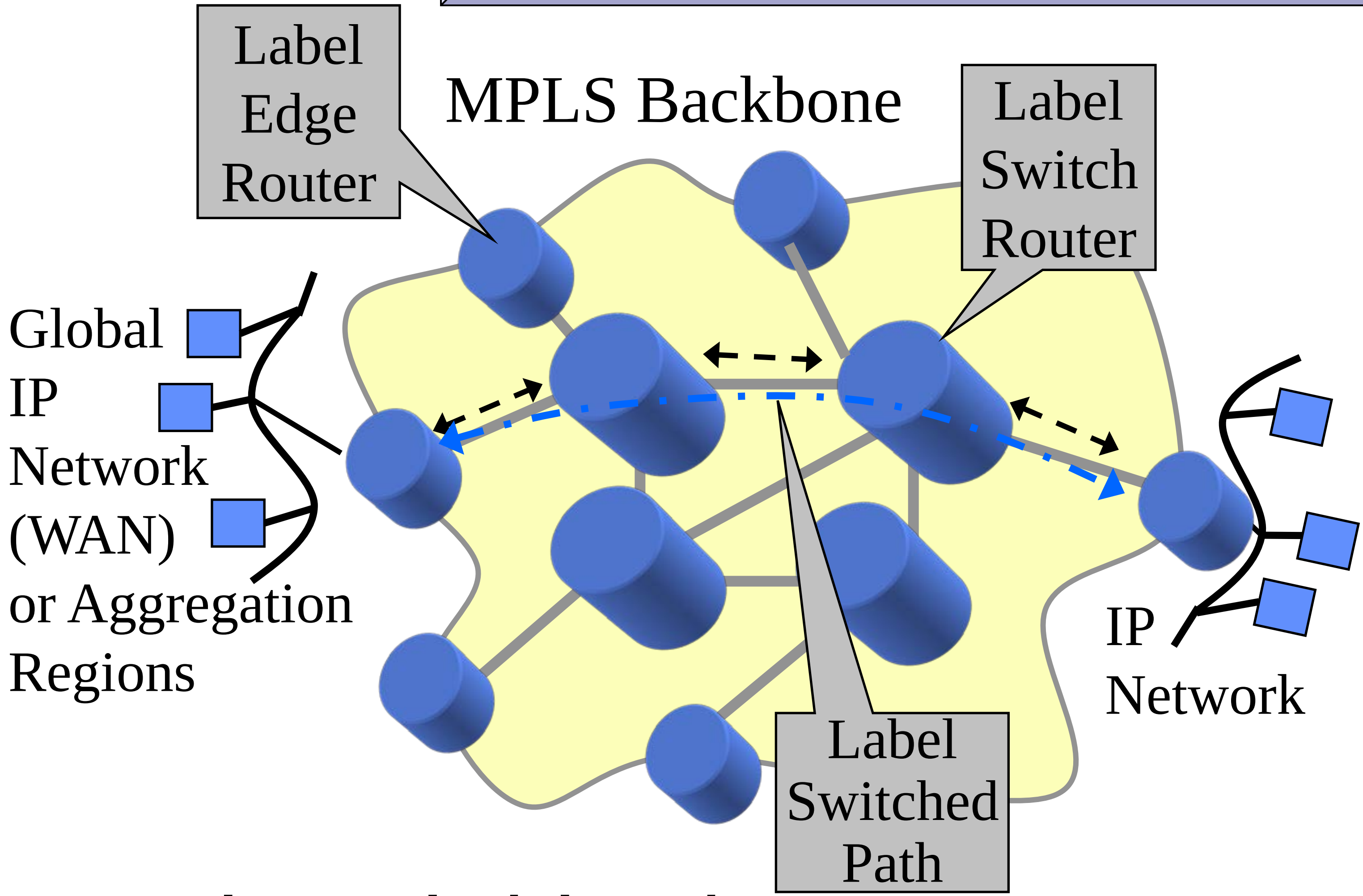
Development of BGP Routing Tables Since 1994



Source: bgp.potaroo.net supported by Univ. of Oregon

MPLS

MPLS-Shim-Header					
Label 20 bit	TC 3 bit	Stack 1 bit	TTL 8 bit	IP-Header	IP-Paket



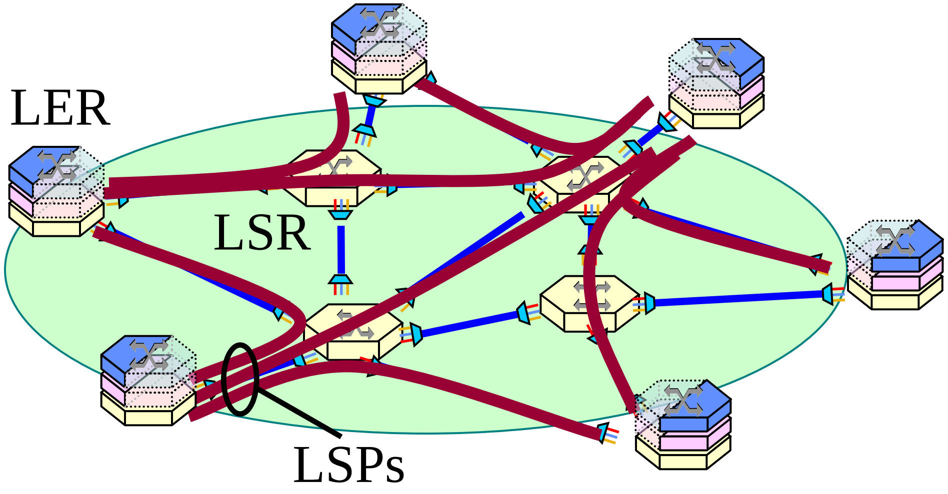
MPLS: Multiprotocol Label Switching

MPLS: Explicit paths & Network Mgnt. Support

Pure IP networks include a limited set of standard measurement

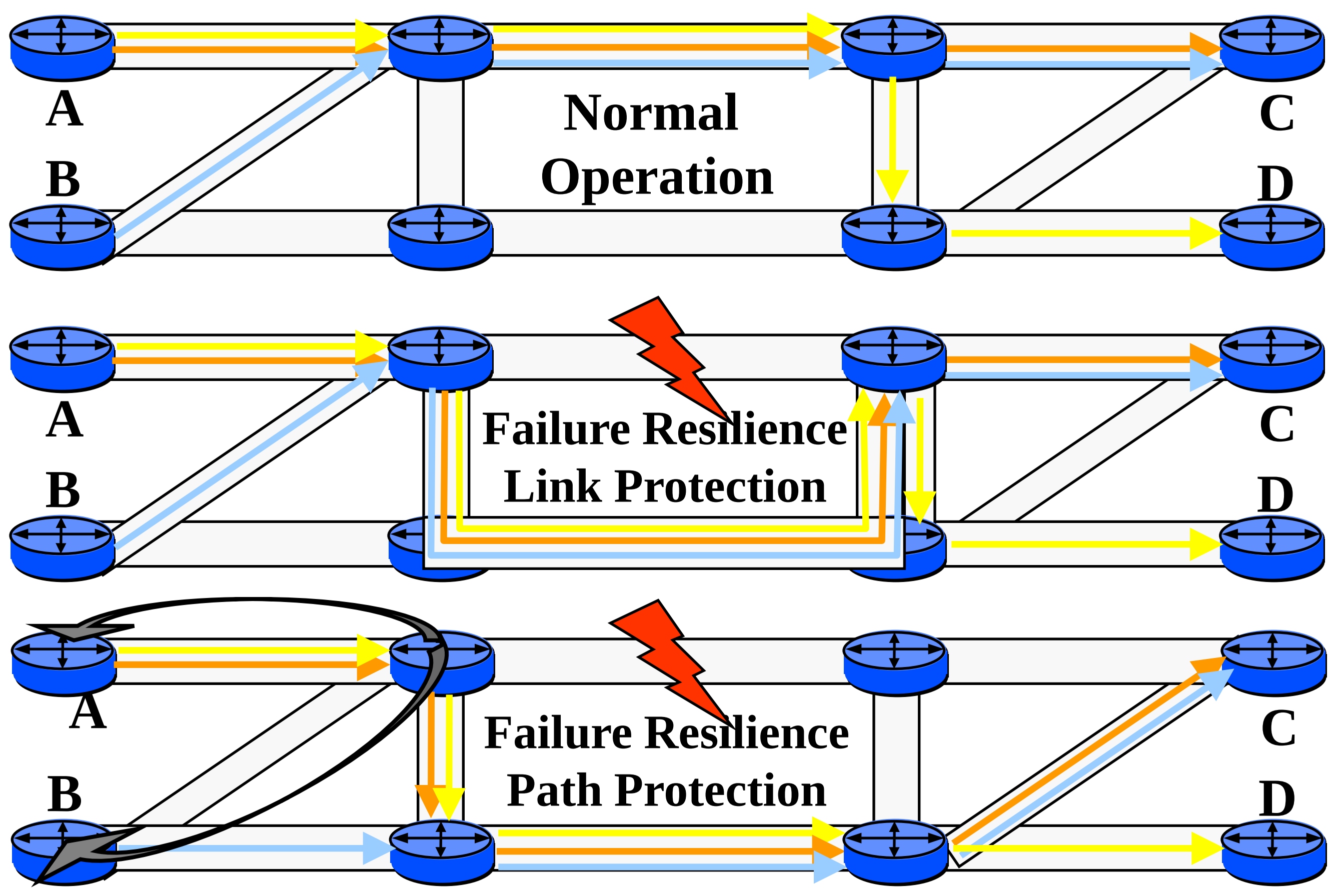
Multiprotocol label switching (MPLS) provides

- ❑ Explicit paths for each traffic flow in a MPLS/IP platform
- ❑ Measurement, OAM and control functions for each path
- ❑ 5- or 15-minute measurement of mean traffic rates is usual
- ❑ Paths between all LER pairs are usual; even per QoS class



The IP core network of DT is based on MPLS since 2003; with extension to almost 1000 locations since 2015; The DE-CIX exchange point also uses MPLS for fast rerouting options

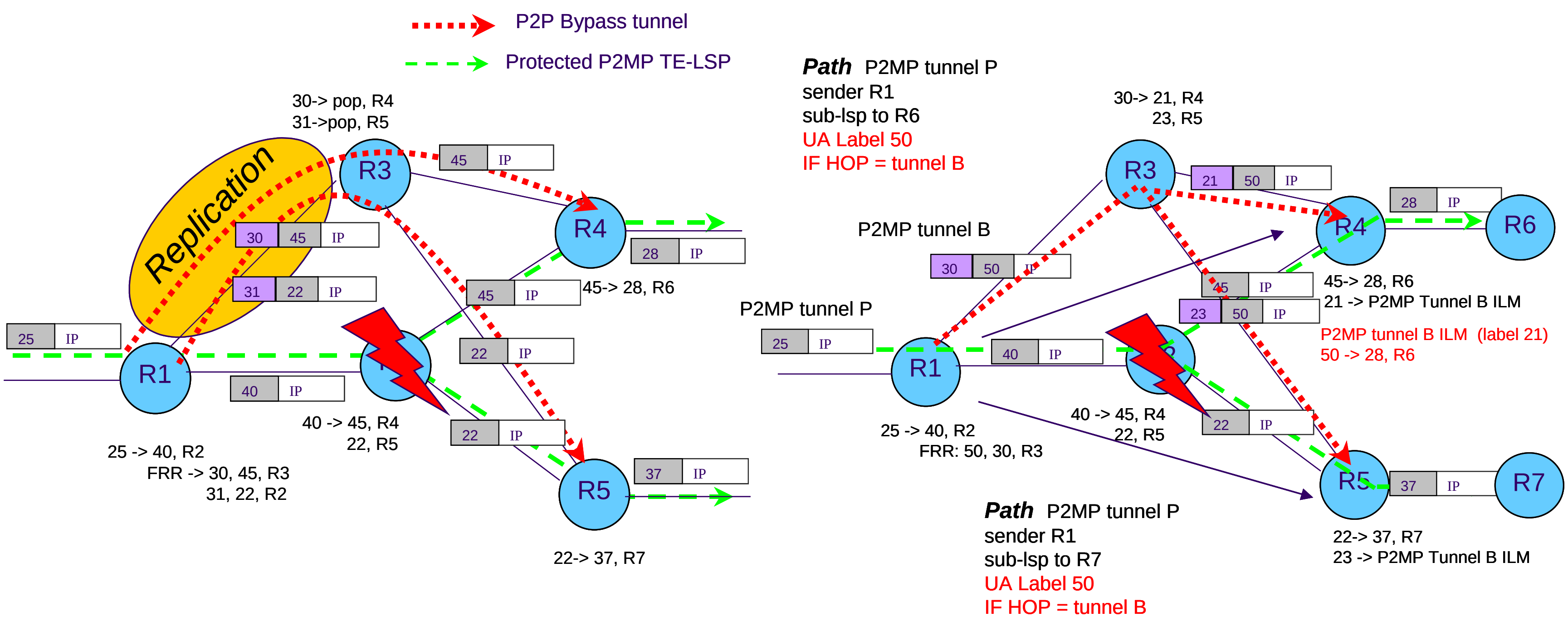
Example: Link ↔ Path Restoration



Path Length:	normal /	Link- /	Path Protection [Hop Count]
AC	3 /	5 /	4
AD	4 /	6 /	4
BC	3 /	5 /	3

Feedback on
Link Failures

BackUp Paths for Multicast: „MLPS-TE Fast Reroute with P2MP Bypass Tunnels“



Example of complex failure recovery schemes avoiding doubled traffic on Point-to-Multi-Point (P2MP) backup paths (RFC 4875)

Source: Presentation of J. Le Roux @ IETF

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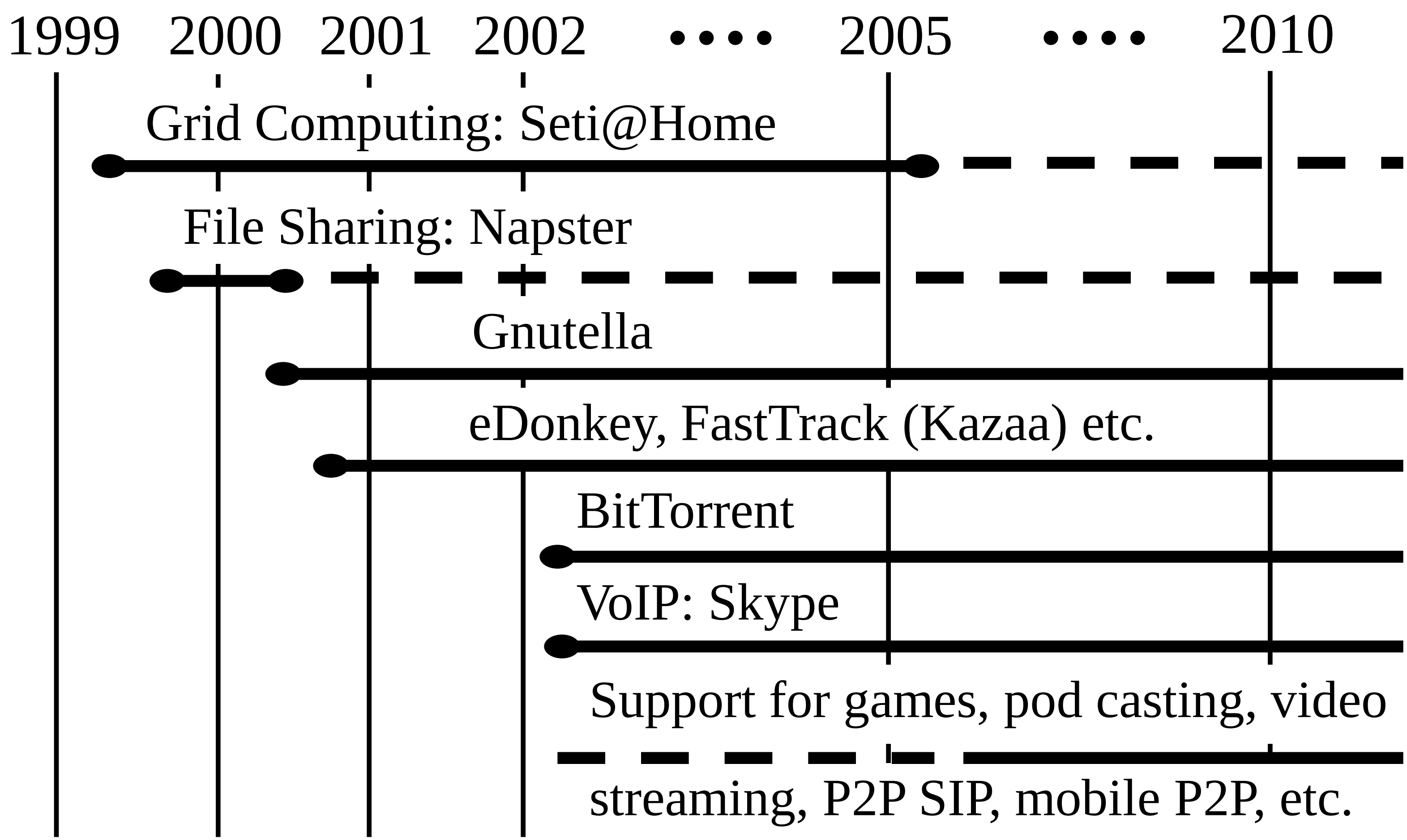
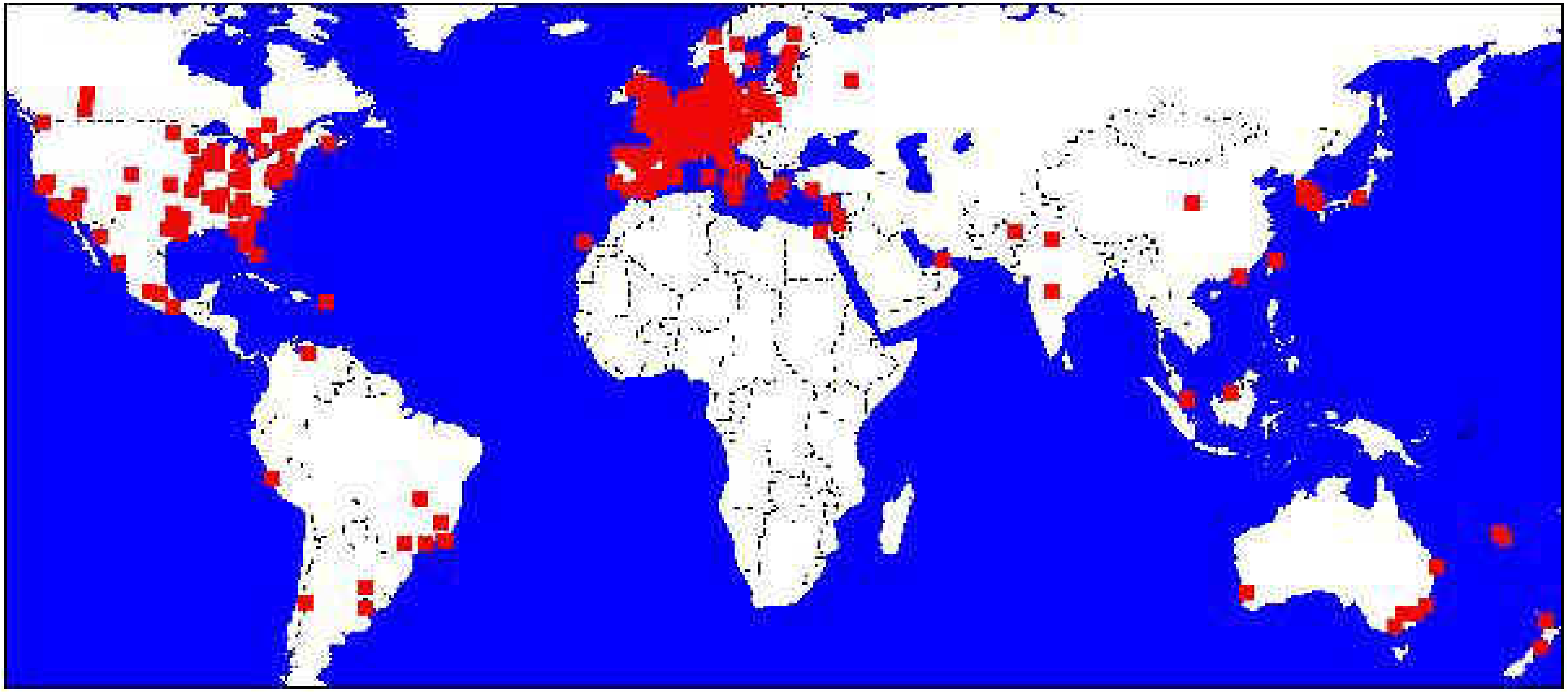
Popular Peer-to-Peer Protocols

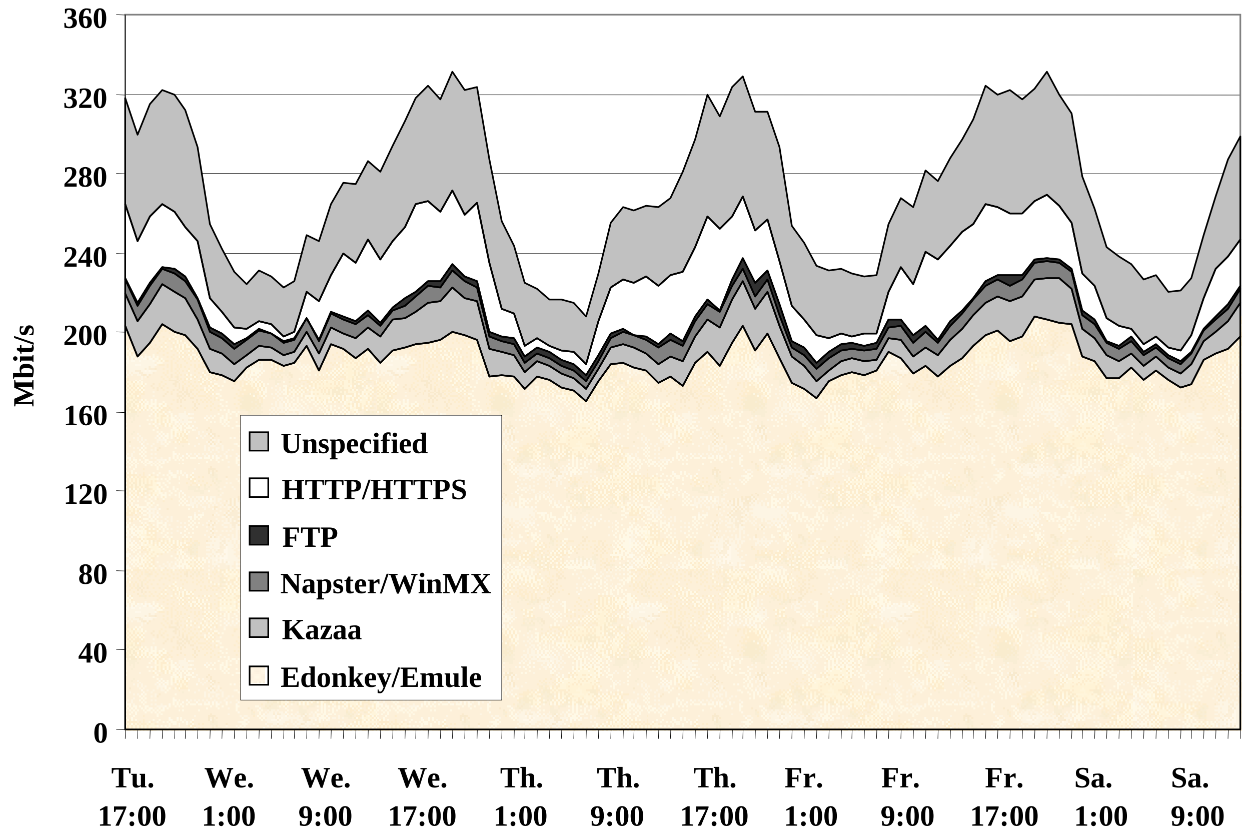


P2P File-Sharing: Fast distribution of large files



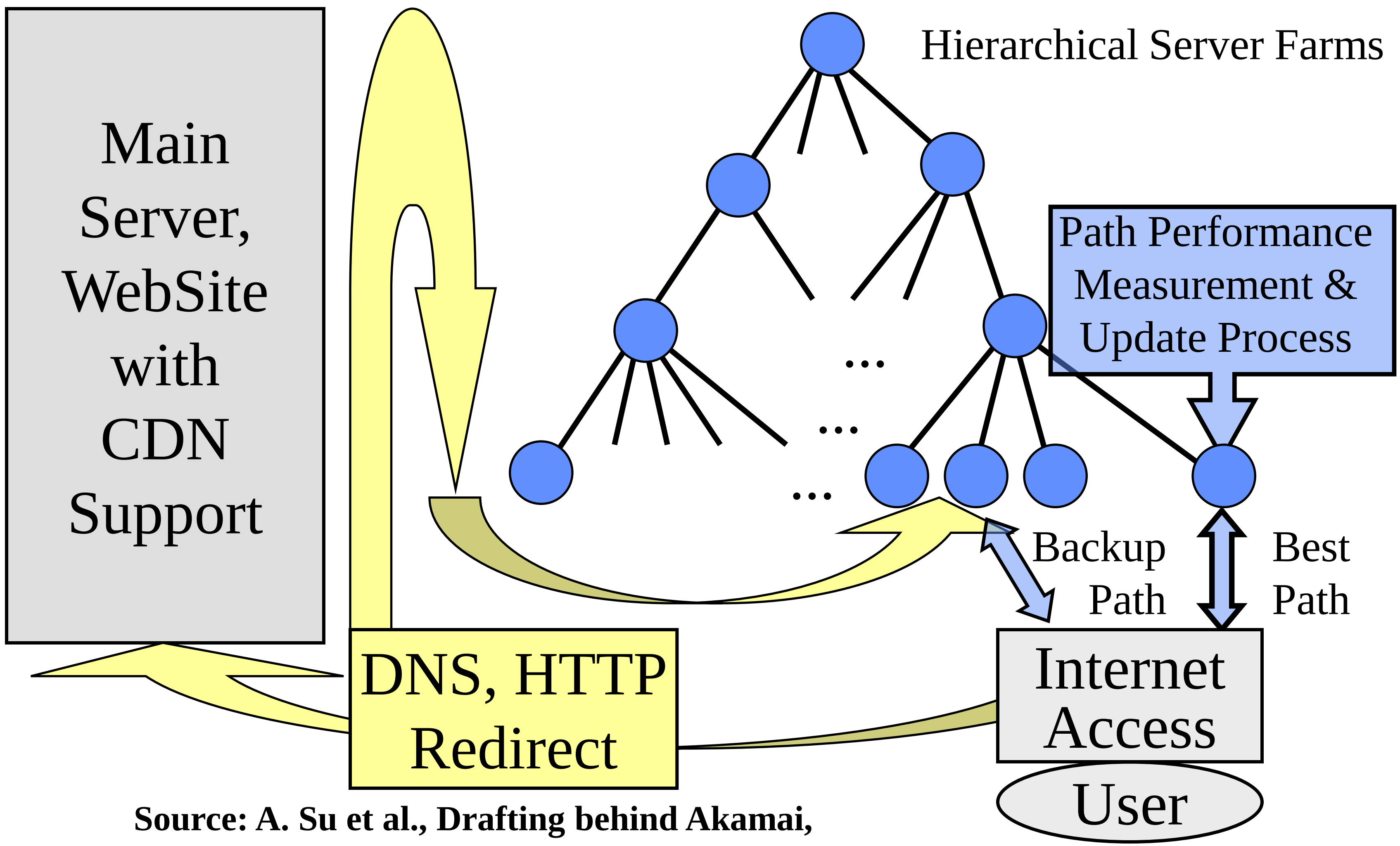
Example: Harry Potter III early propagation after 2 hours on May 28th 2004 (Source: *www.itic.ca/DIC/News/archive.html*)
Availability/replication of data as needed i.e. depends on requests

Traffic profile over 4 days dominated by P2P



- Port-based measurement on a backbone link in Germany in 2003:
- 70% P2P traffic portion; > 60% eDonkey/eMule

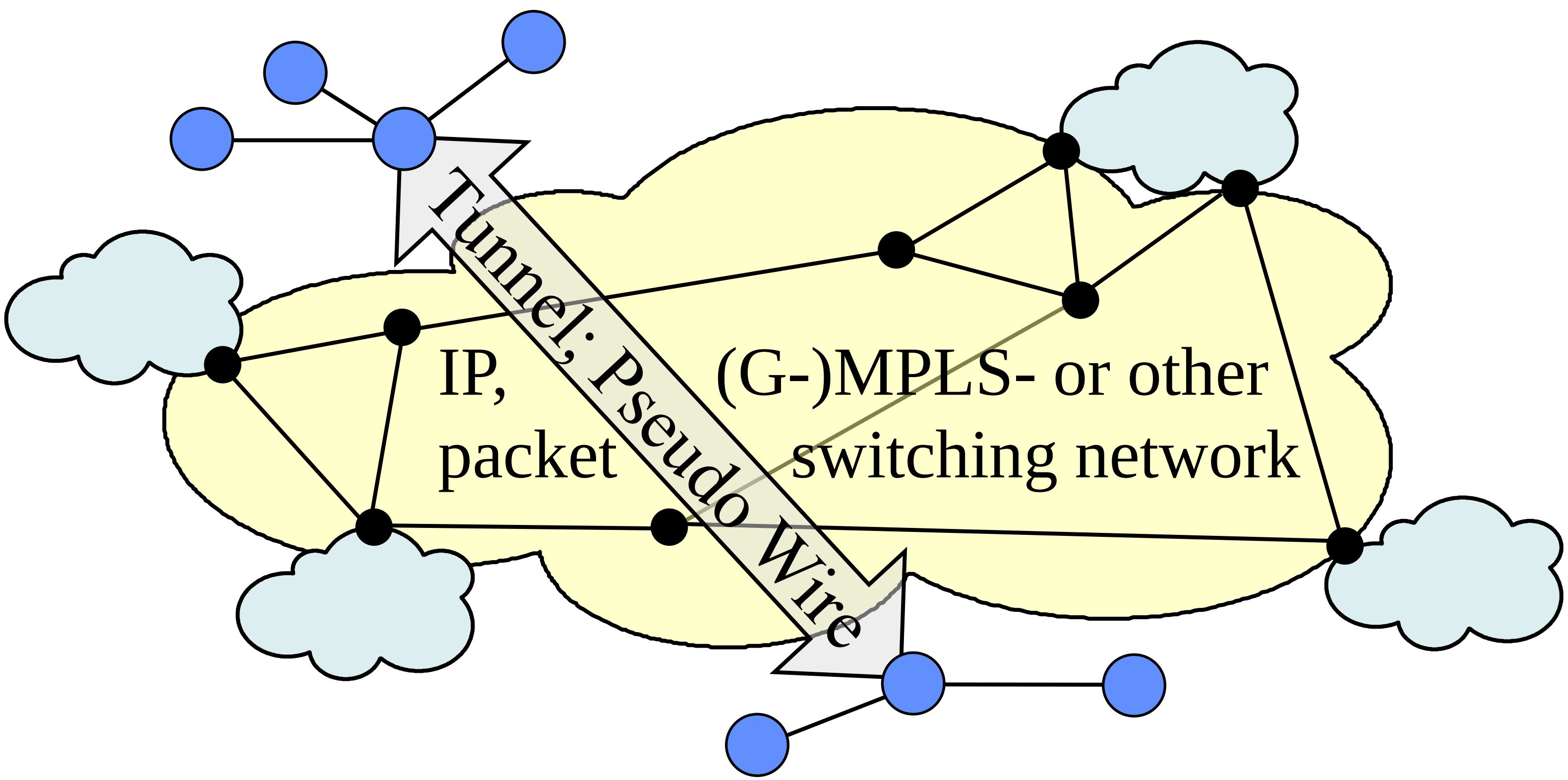
Content Delivery Overlays (CDN, Akamai, Google ...)



Source: A. Su et al., Drafting behind Akamai, IEEE/ACM Trans. on Networking 17 (2009) 1752–1765

Lower layers overlays standardized by IETF

- Pseudo wire emulation edge-to-edge (PWE3 working group)
- Layer-3 Virtual Private Networks (& L2-VPN, L1-VPN WG)
- Tunnneling; Encapsulation; Network protocol X over Y; …



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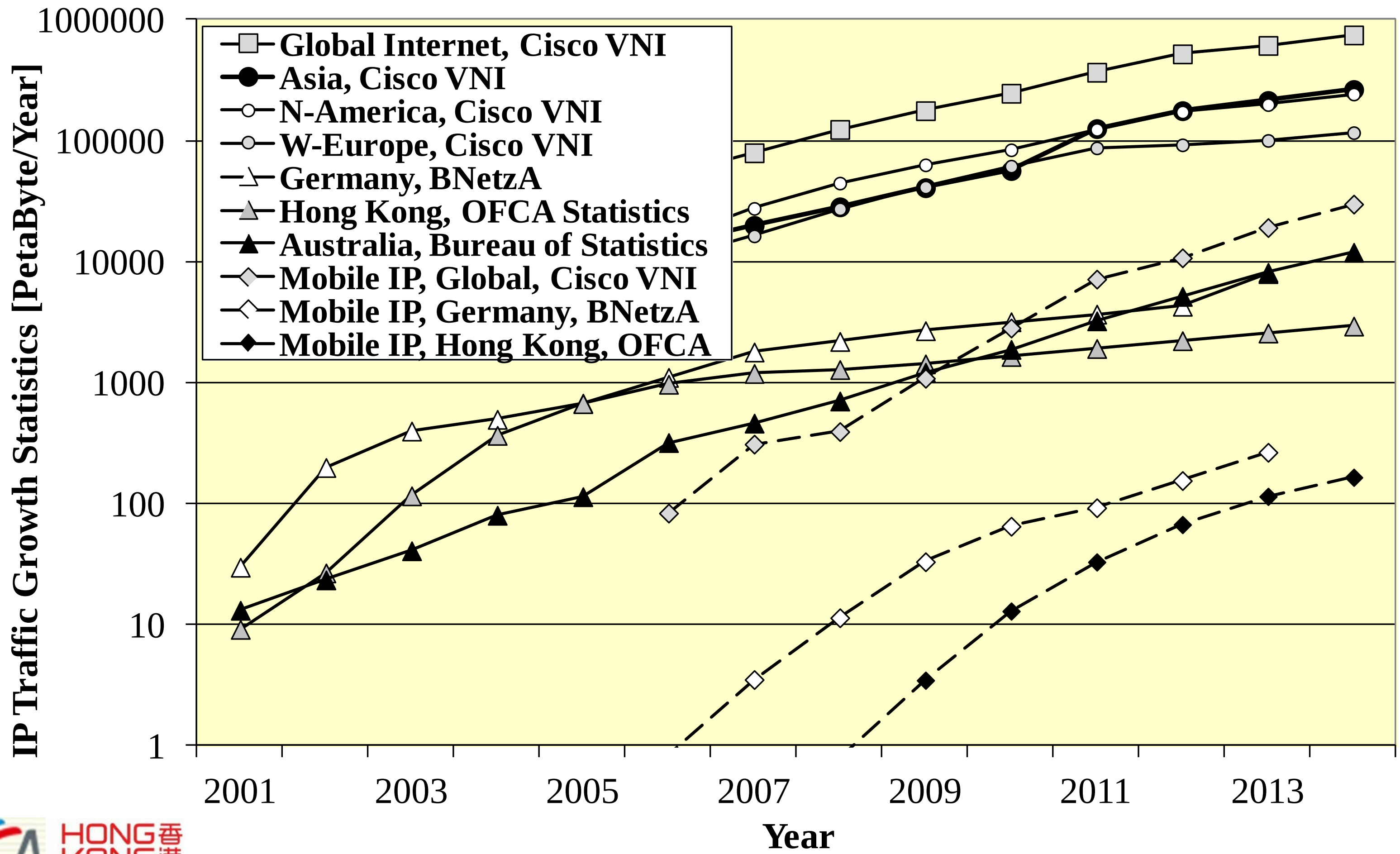
Statistics on Internet Traffic Growth

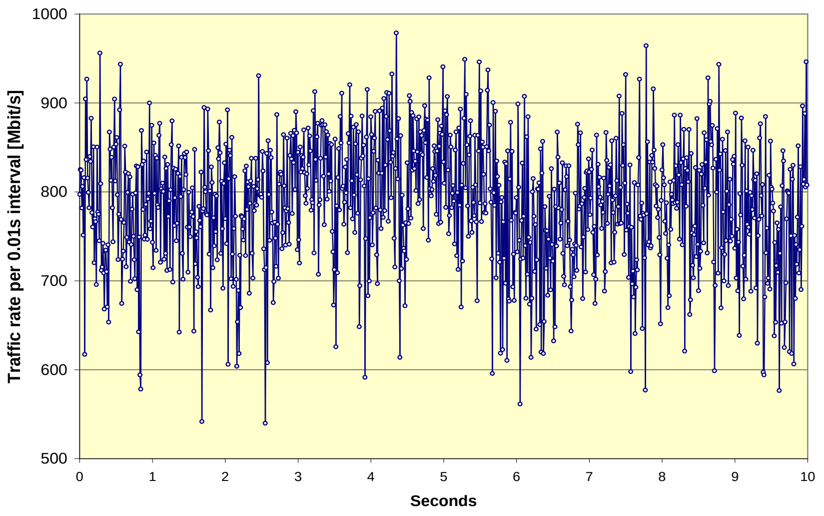


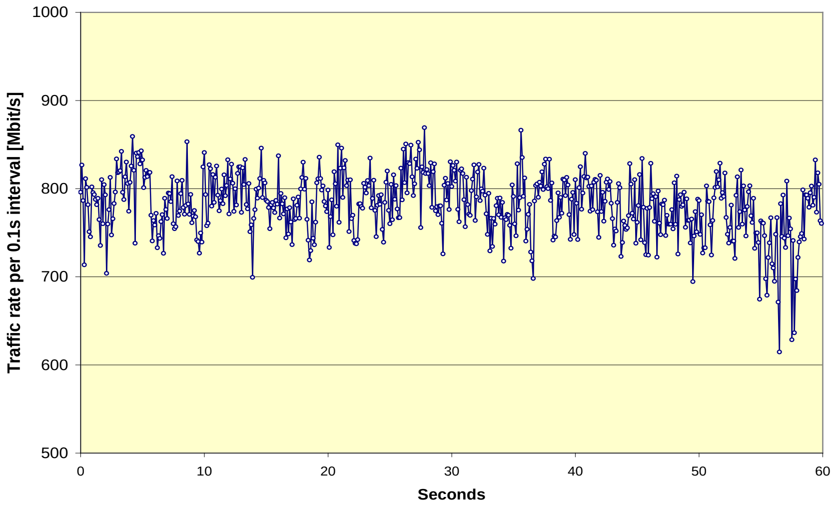
Sources: Cisco Systems, Visual Networking Index <www.cisco.com>
Australian Bureau of Statistics <http://abs.gov.au/ausstats/abs@.nsf/mf/8153.0>
Hong Kong OFCA <www.ofca.gov.hk>
Germany, Bundesnetzagentur <www.bundesnetzagentur.de>

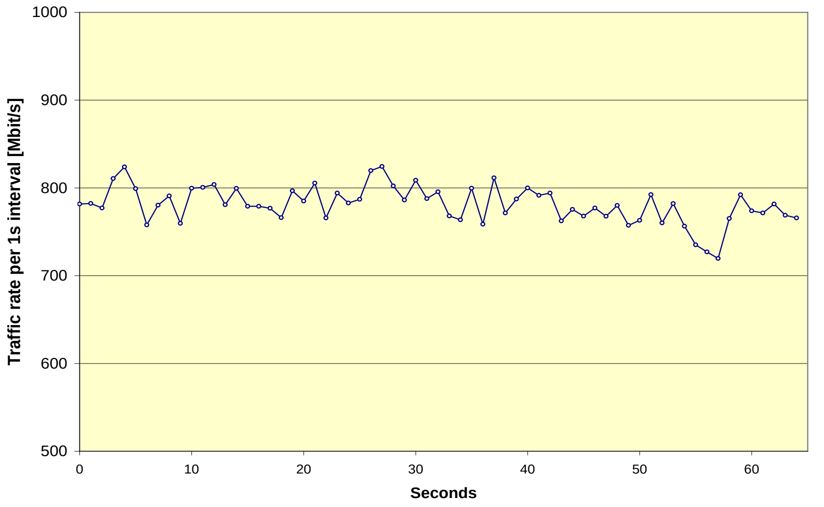
Traffic traces in multiple (short) time scales

Evaluation of a traffic trace in 0.01s➔, 0.1s🡻 and 1s🡾 intervals on broadband access platform:

Variability is decreasing on larger time scales, although long range dependency persists

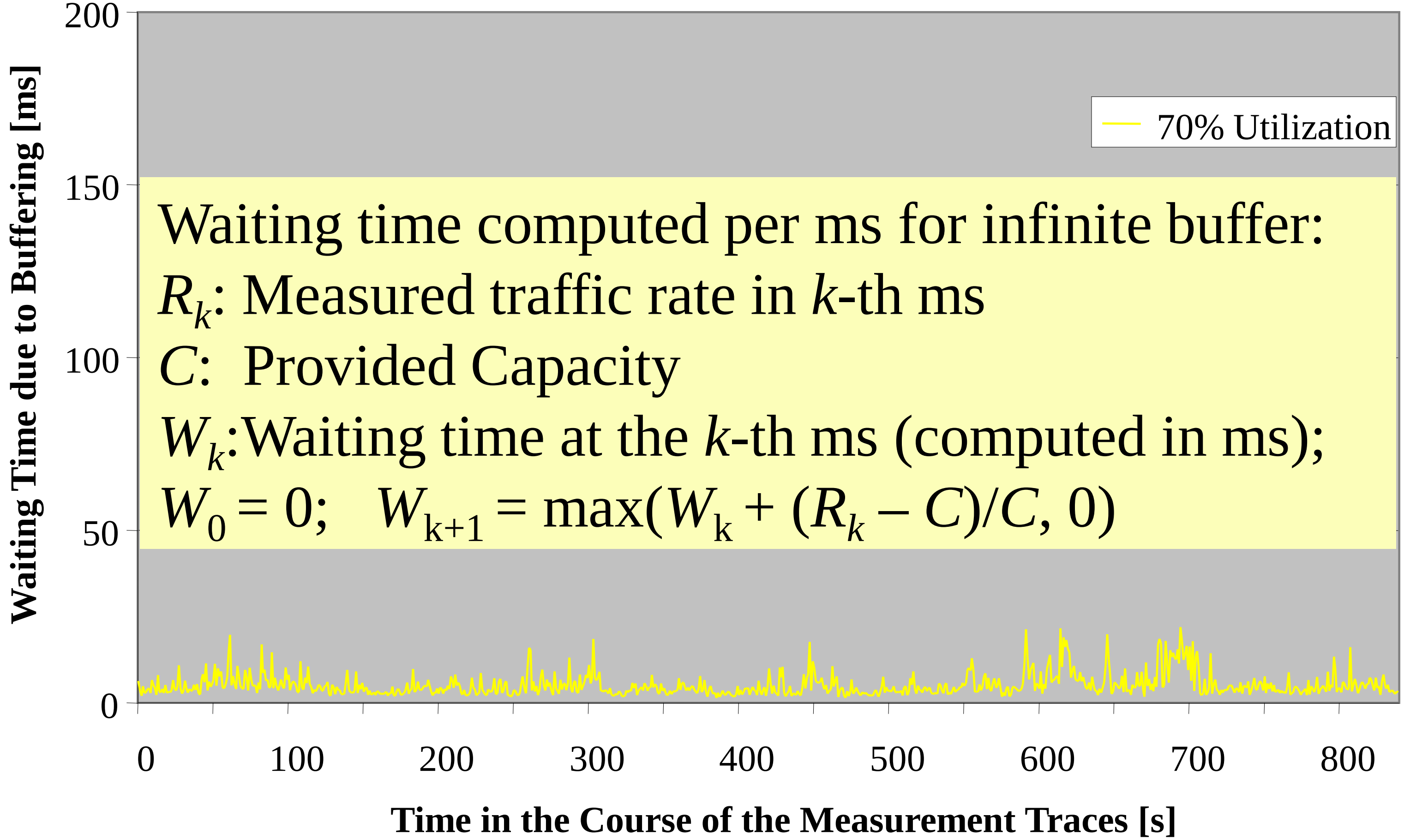




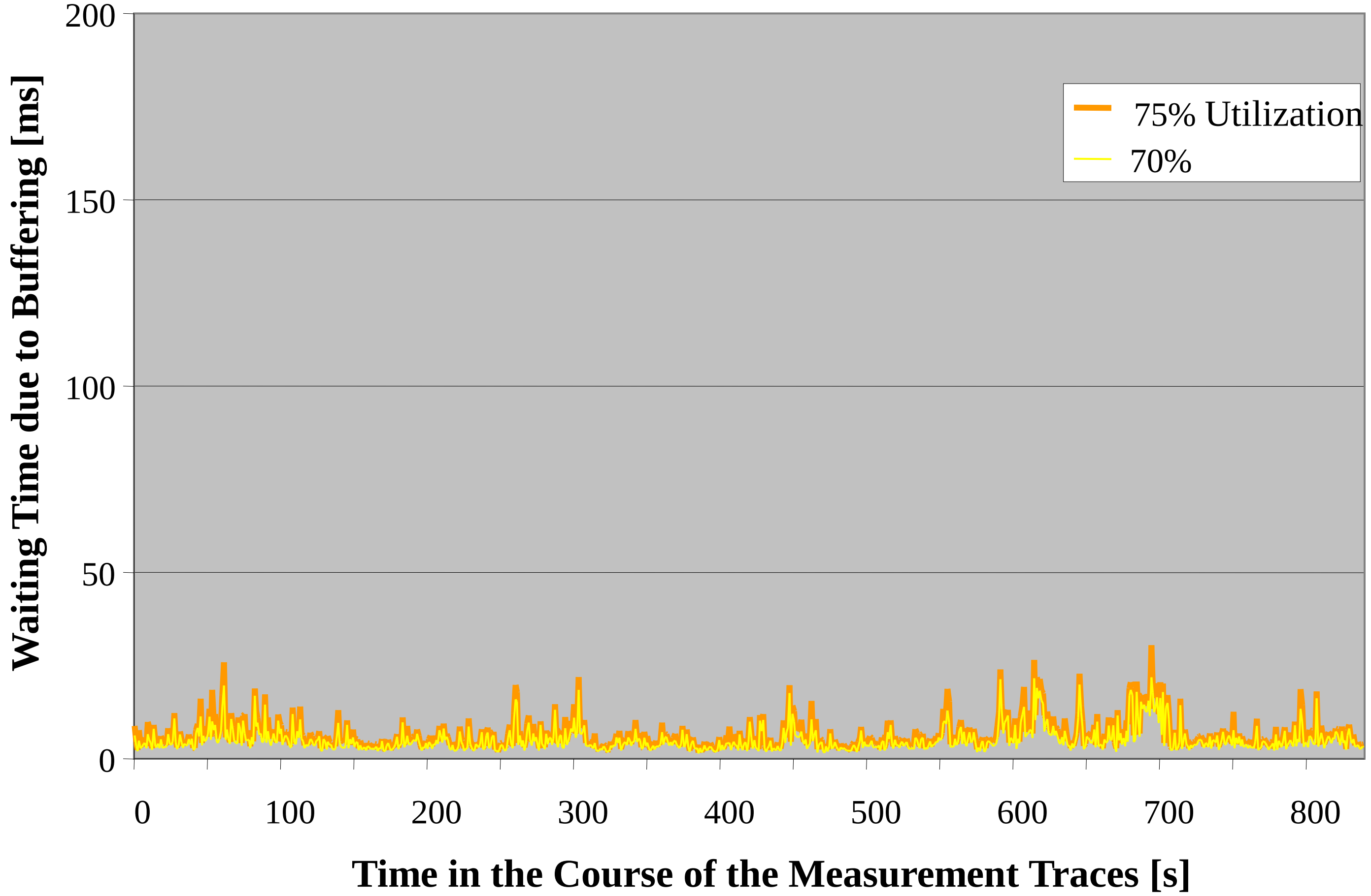


Waiting time in the course of a trace of an MPLS flow

Mean traffic rate: 18 Mb/s; Provided capacity: 26 Mb/s

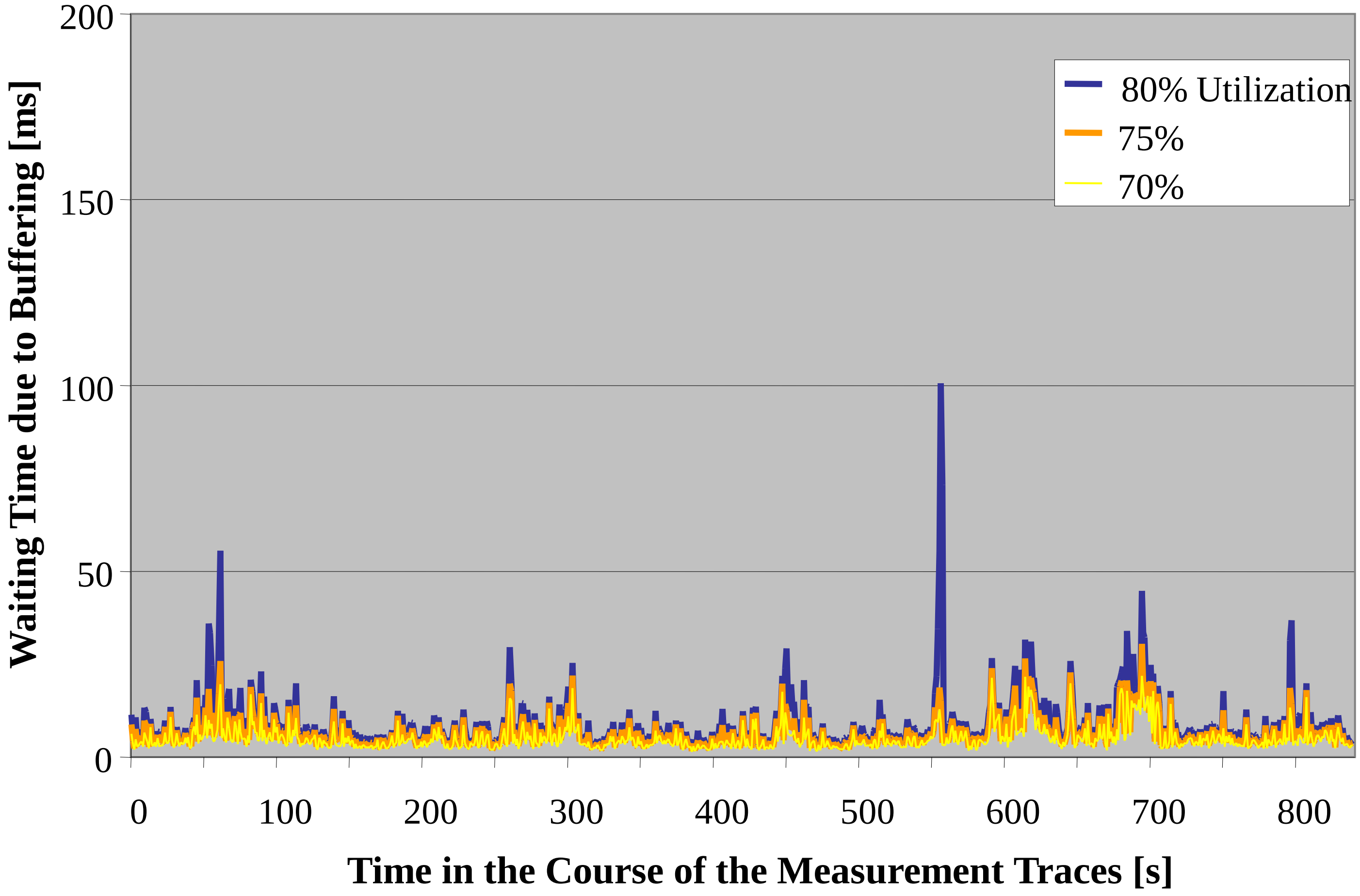


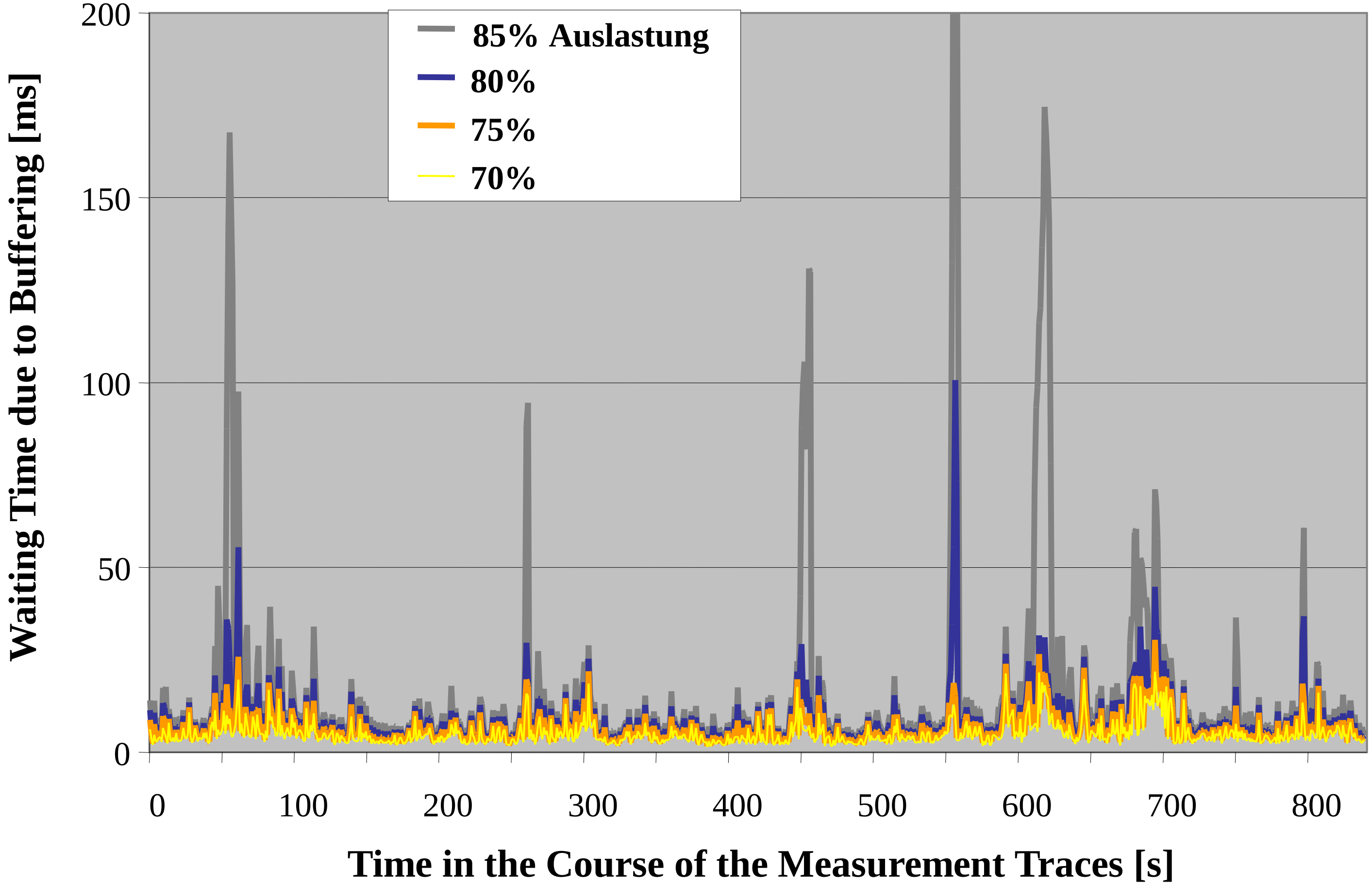
Waiting time in the course of a trace of an MPLS flow
Mean traffic rate: 18 Mb/s; Provided capacity: 24 or 26 Mb/s



Waiting time in the course of a trace of an MPLS flow

Mean traffic rate: 18 Mb/s; Provided capacity: 22.5, 24, 26 Mb/s




85% Auslastung
80%
75%
70%
200
150
100
50
0
Waiting Time due to Buffering [ms]
0
100
200
300
400
500
600
700
800
Time in the Course of the Measurement Traces [s]