ICT Developments: Technological, Architectural, Traffic Engineering and QoS Challenges

Paul J. Kühn
Institute of Communication Networks and Computer Engineering
University of Stuttgart
Pfaffenwaldring 47, 70569 Stuttgart
kuehn@ikr.uni-stuttgart.de

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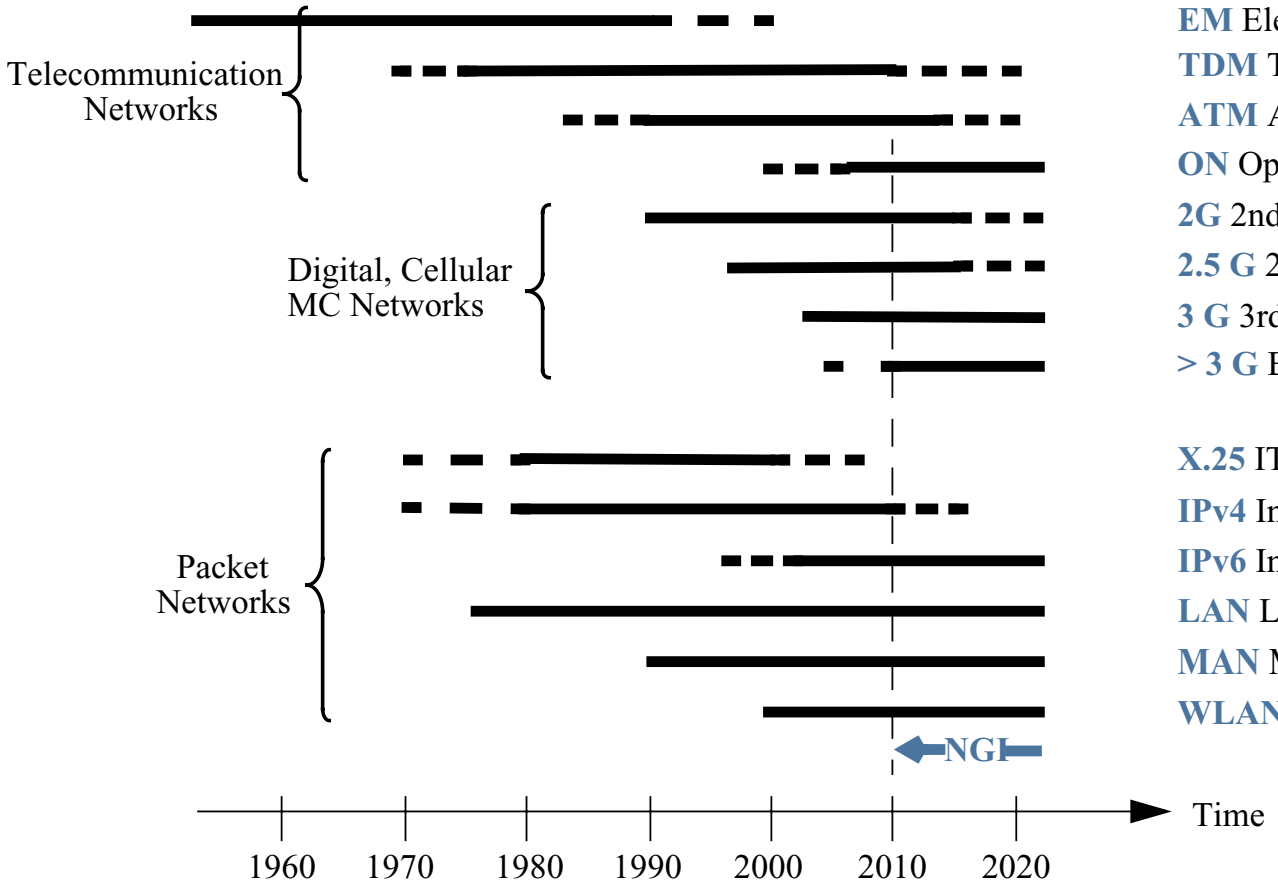
Outline

1. **Development of Network Technologies and Services**
   1. Digital Telecommunication Networks
   2. Packet Networks
   3. Mobile Communication Networks
   4. Services and Applications
2. **Network Convergence**
   1. Horizontal and Vertical Integration
   2. Towards IP-Based Networks
   3. Ambient, Ubiquitous and Nomadic Communications
3. **Technical Challenges of NGN**
   1. Architectures and Platforms
   2. Component Technologies
   3. Quality of Service and Traffic Engineering
   4. Network Management and Self-Organization
   5. Security
4. **Conclusions**

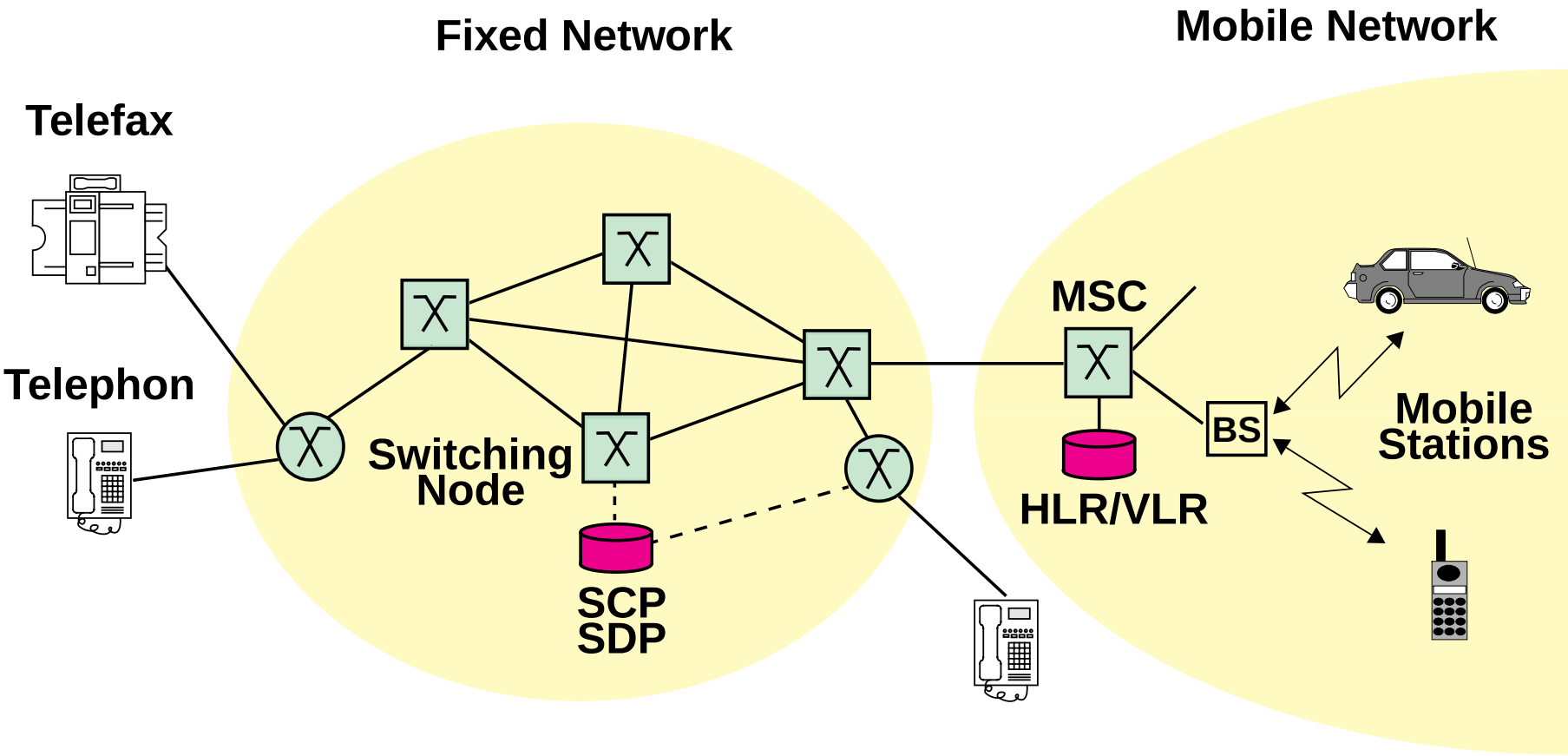
Development of Network Technologies



EM Electromechanical Technology
TDM Time Division Multiplex
ATM Asynchronous Transfer Mode
ON Optical Networks
2G 2nd Generation MC Networks
2.5 G 2.5nd Generation MC Netw.
3 G 3rd Generation MC Networks
> 3 G Beyond 3rd Generation MC Net

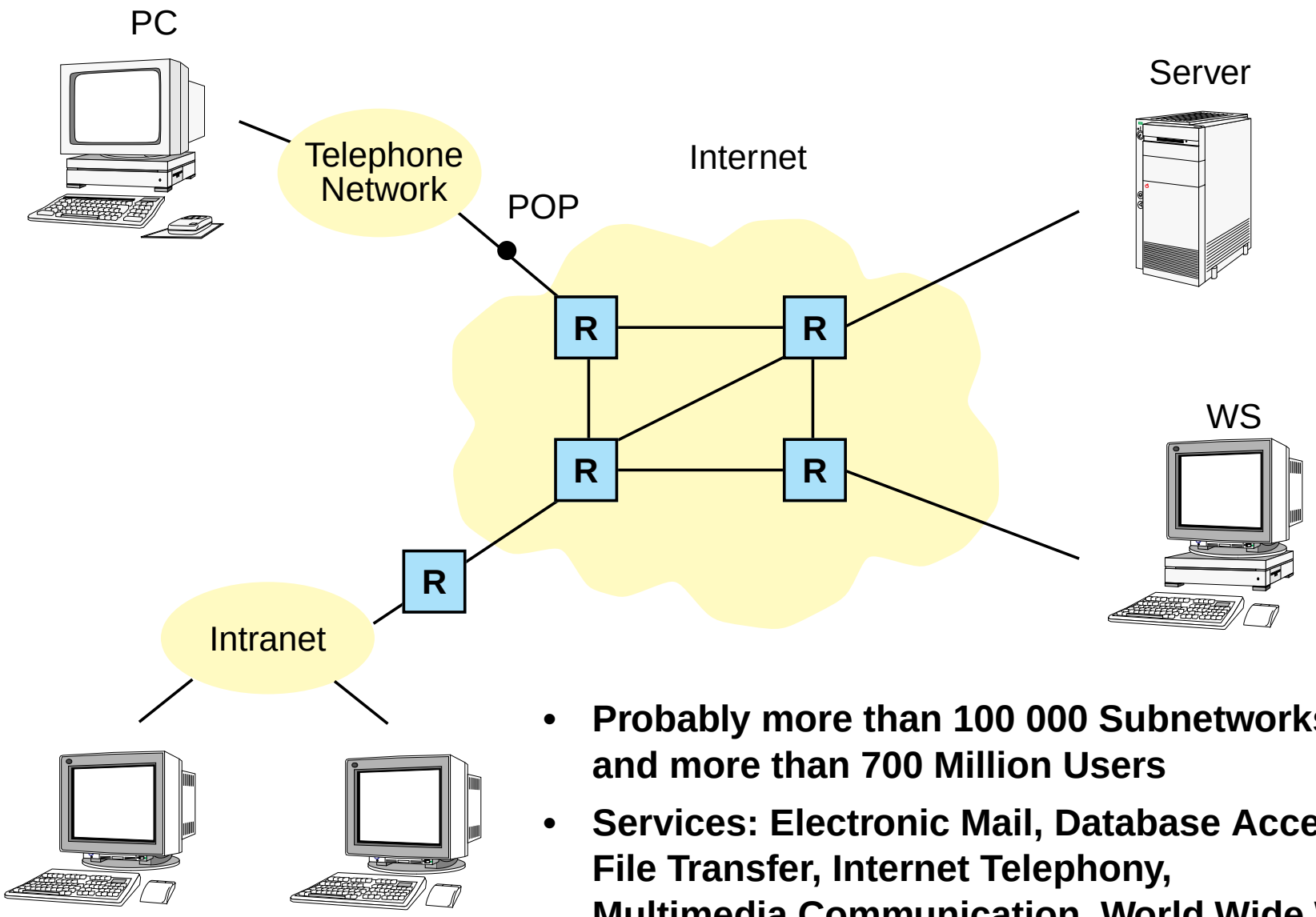
X.25 ITU Packet Standard
IPv4 Internet Protocol Version 4
IPv6 Internet Protocol Version 6
LAN Local Area Networks
MAN Metropolitan Area Networks
WLAN Wireless LAN

Telecommunication Networks



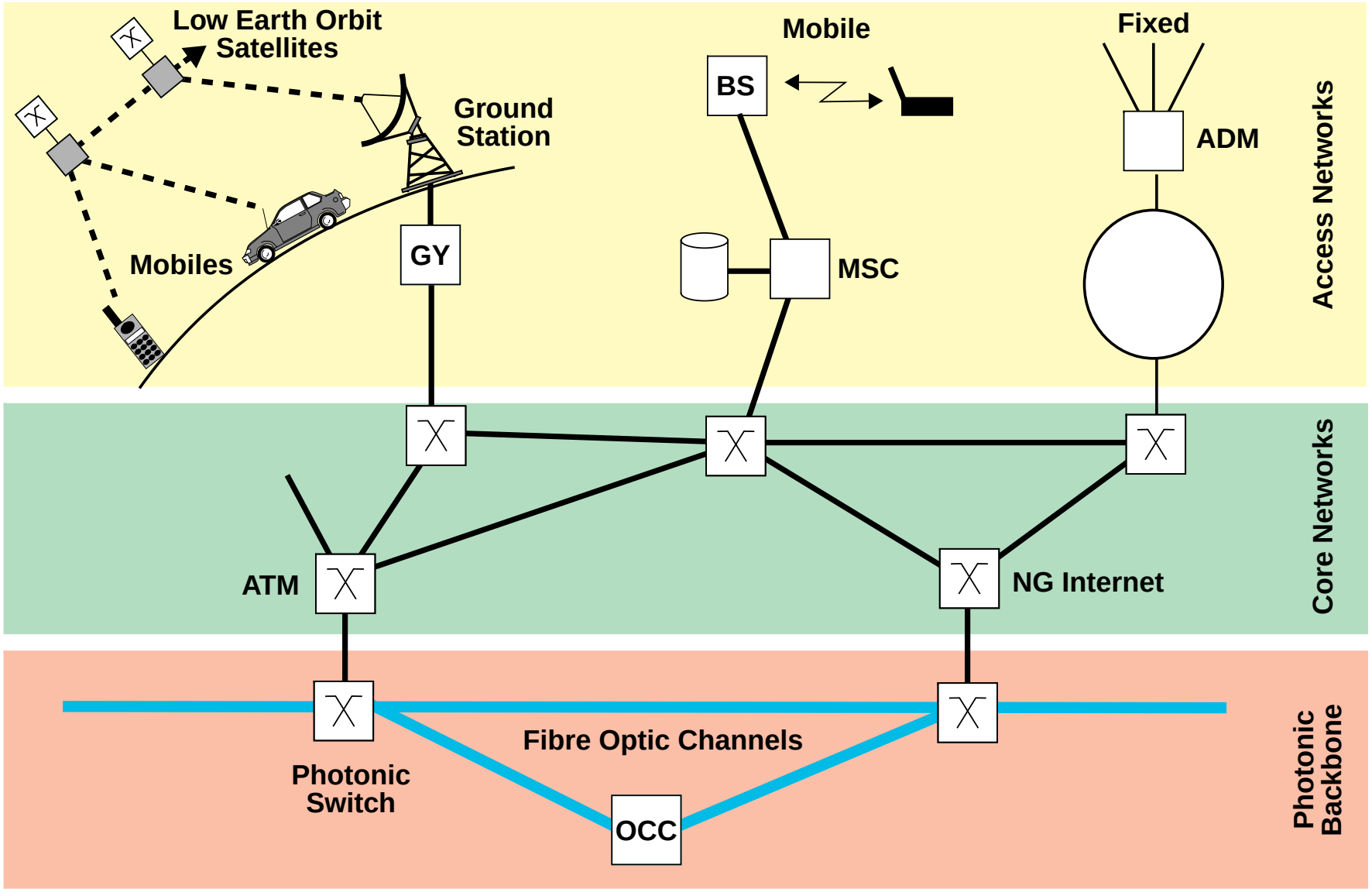
- 1200 Million Subscribers (Fixed Network) Annual Growth 10%
- 1400 Million Subscribers (Mobile Networks) Annual Growth 50%
- Intelligent Network Services (IN)

Computer Communication Networks



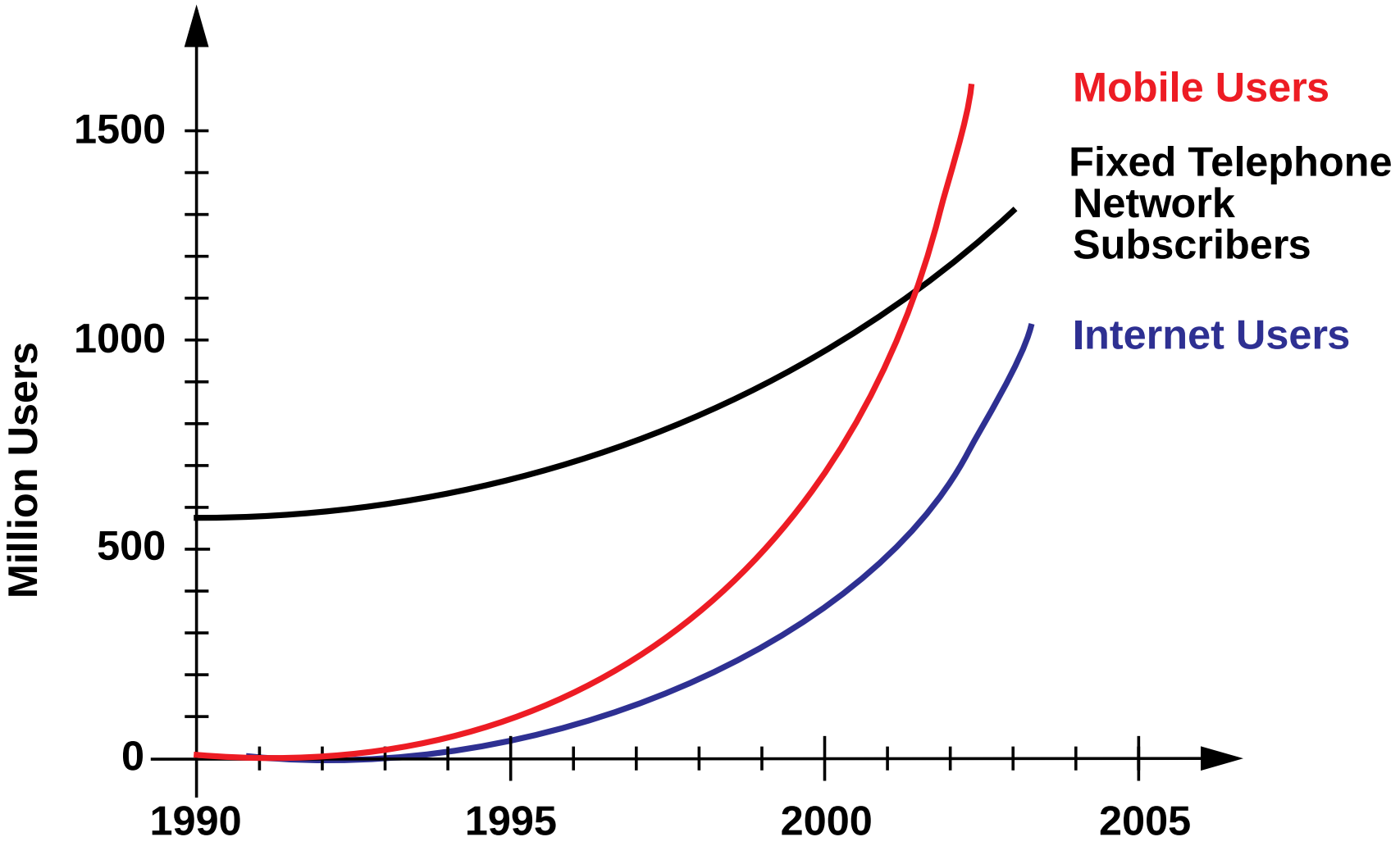
- **Probably more than 100 000 Subnetworks and more than 700 Million Users**
- **Services: Electronic Mail, Database Access, File Transfer, Internet Telephony, Multimedia Communication, World Wide Web, Peer-to-Peer**

Technological Developments

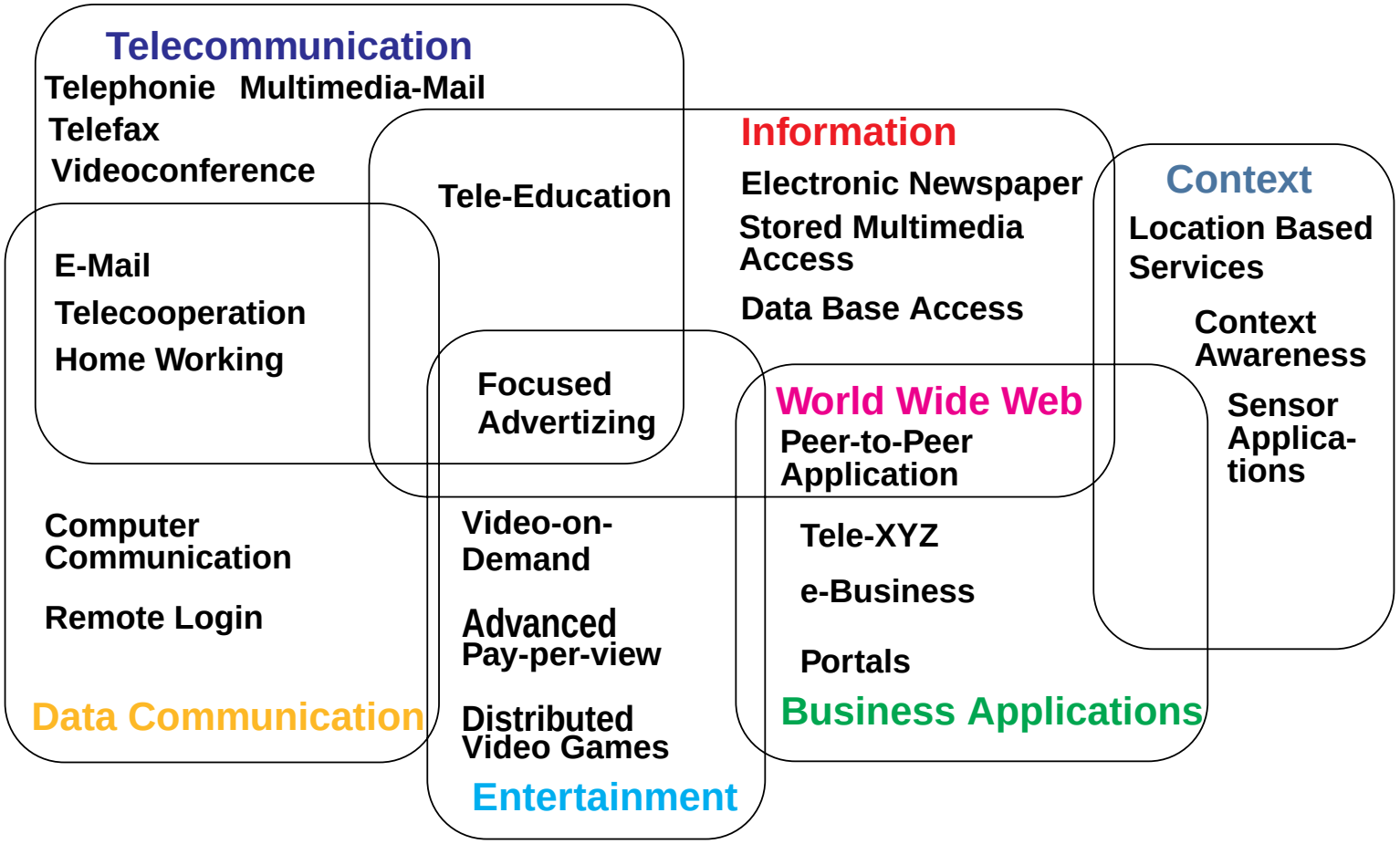


Development of User Numbers

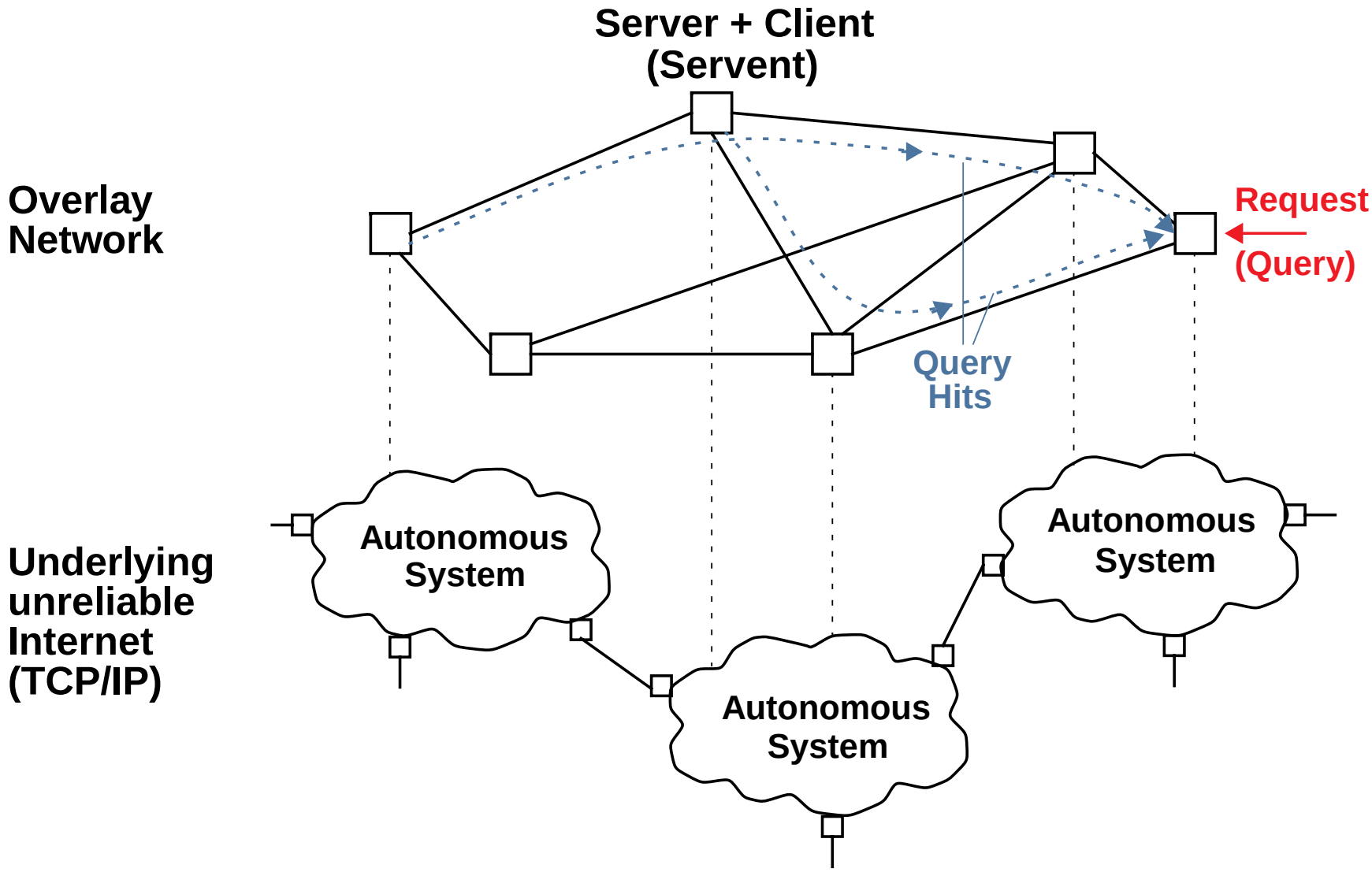
Source: ITU News 2/2002



Application Areas and Communication Services

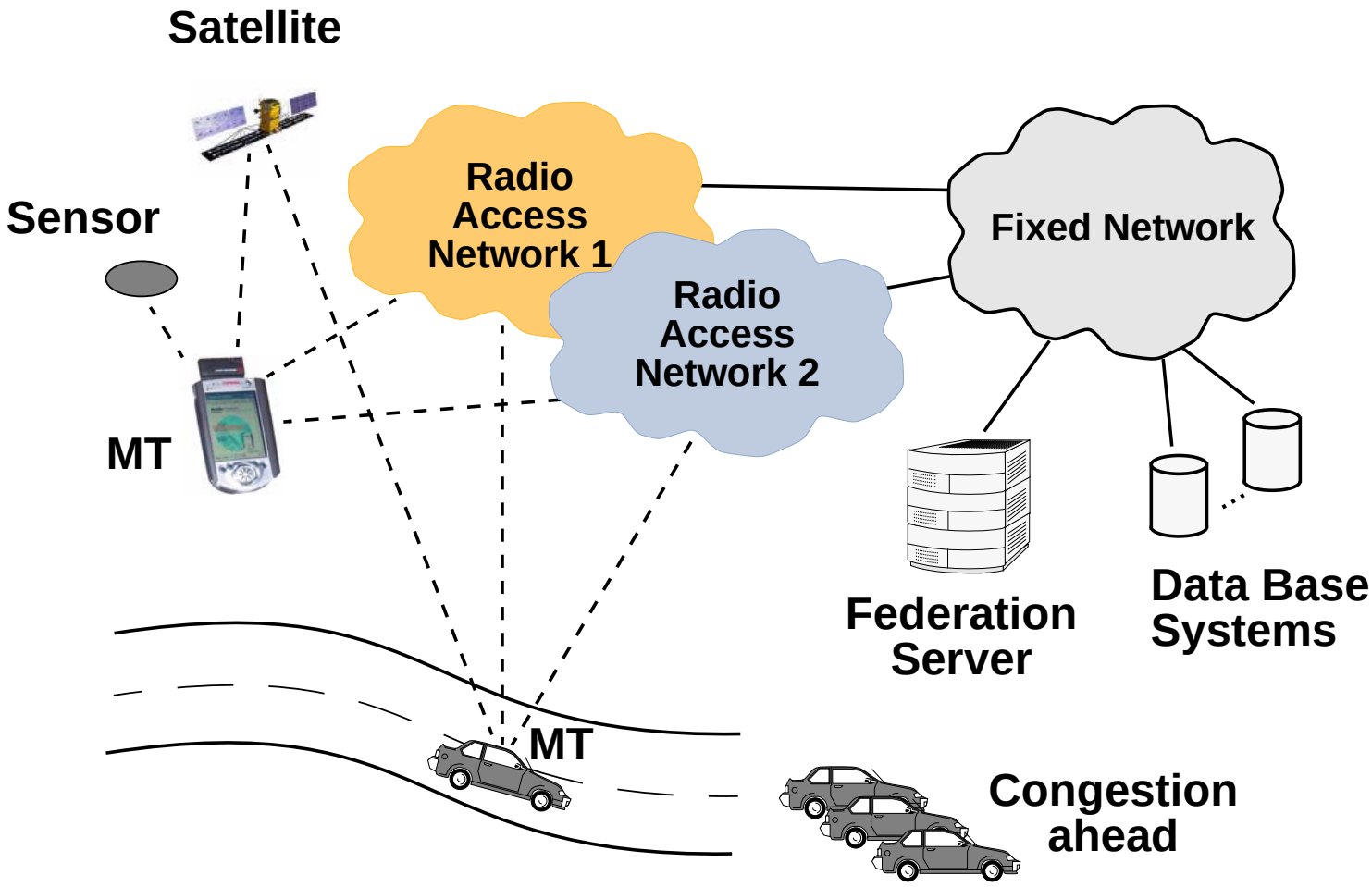


Peer-to-Peer File Sharing



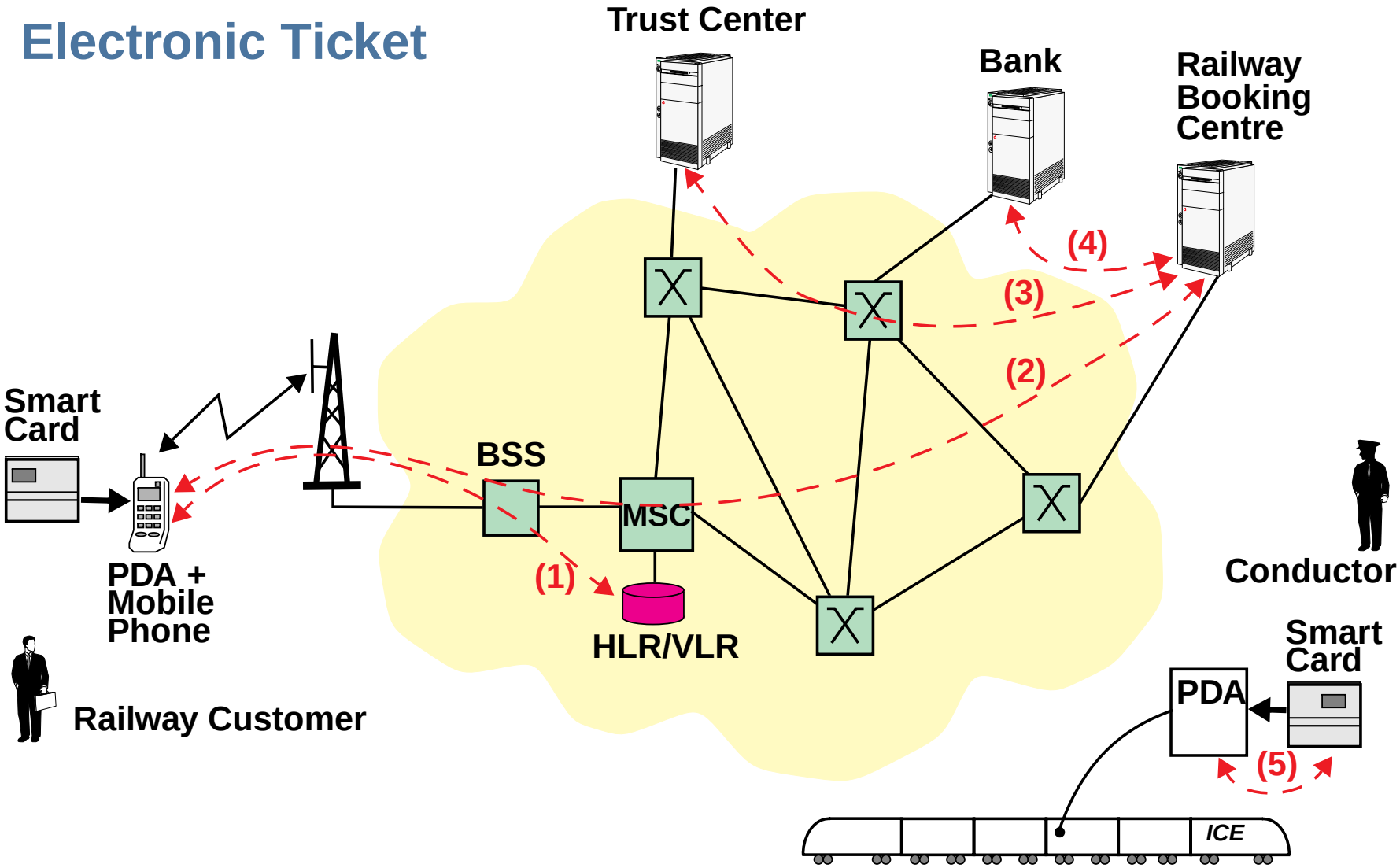
Application Scenario

Navigation Support



Application Scenario

Electronic Ticket



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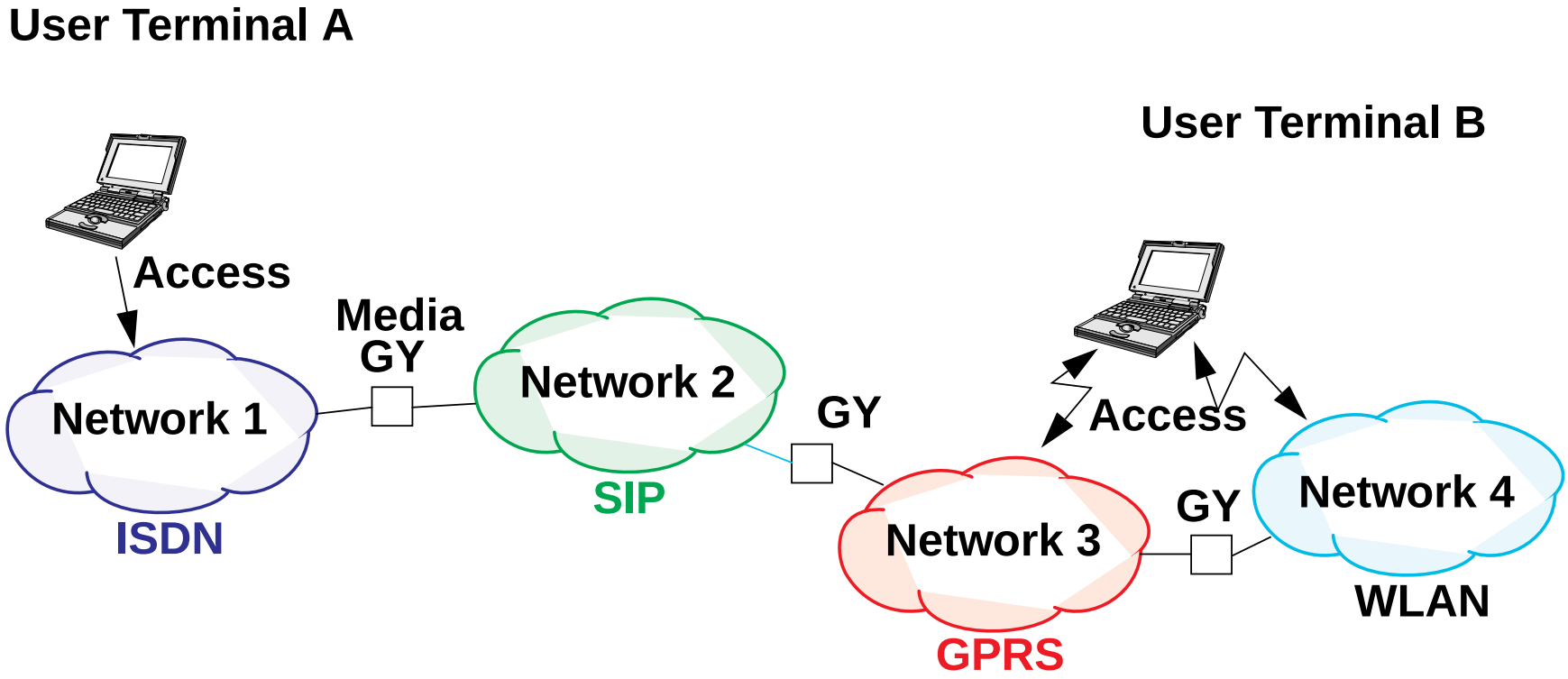
Network Convergence

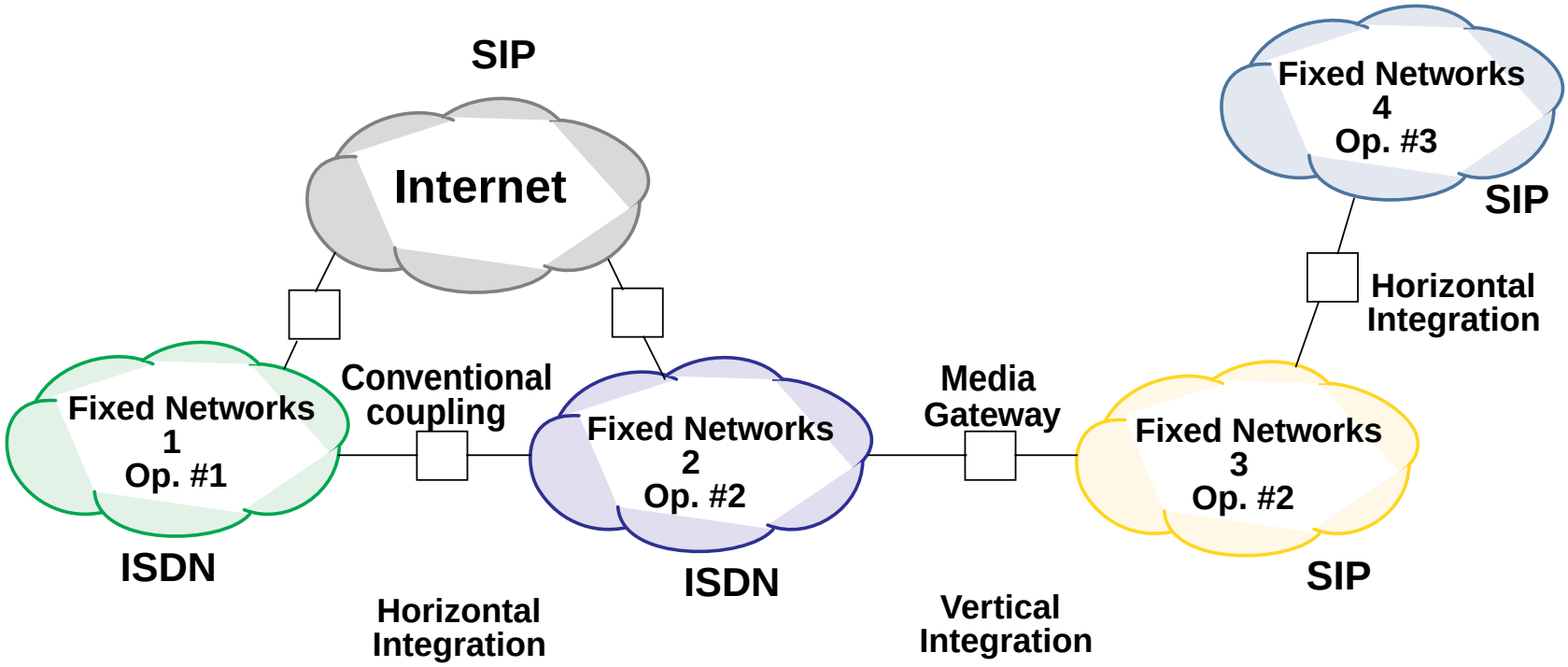


- Users may have access to networks of different technologies
- Communication across networks of identical / different technologies
- "Always best connected"
- Wide spectrum of services

Horizontal and Vertical Integration

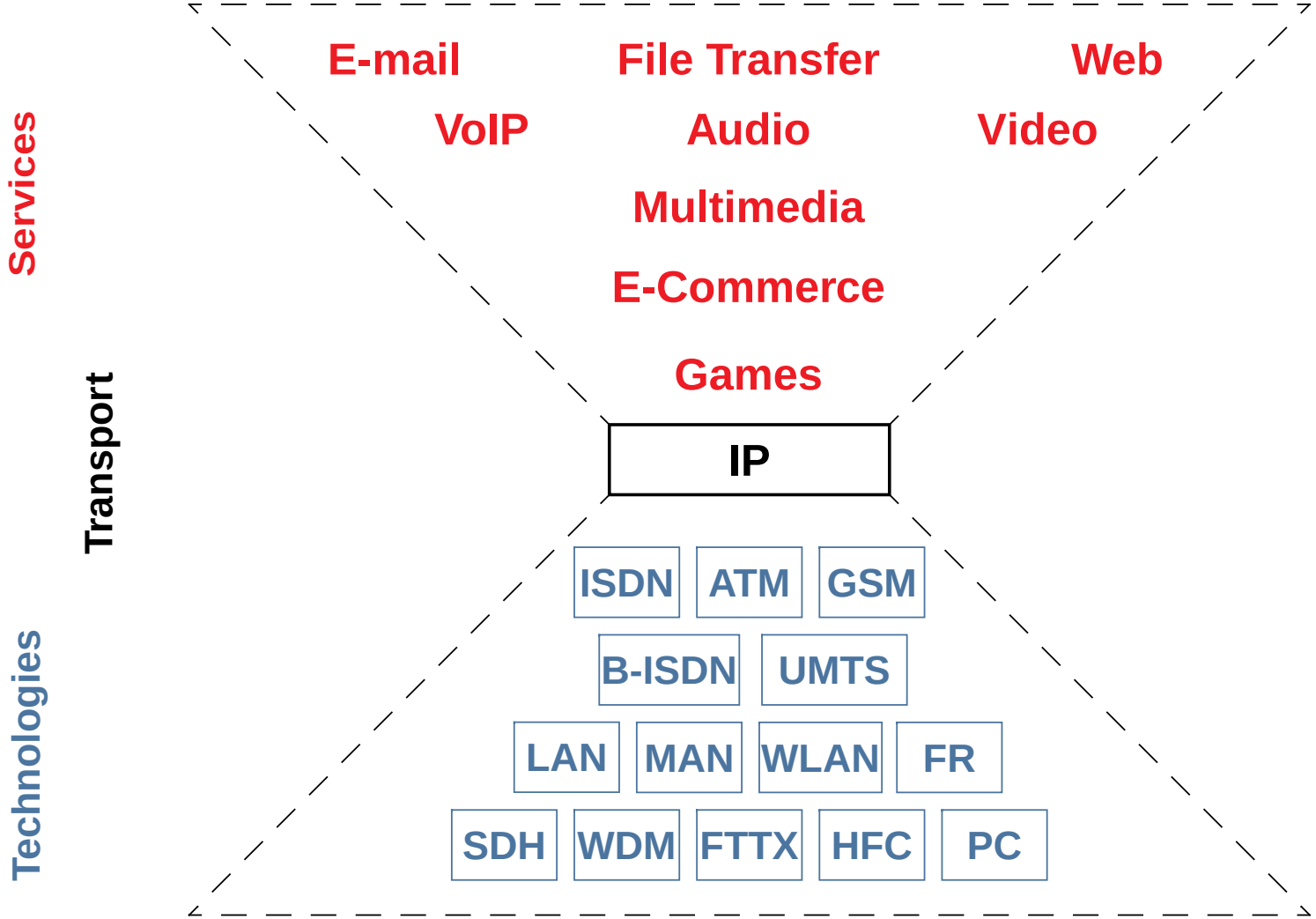
Statements: Existing networks: ISDN, Mobile Networks, Internet, ...
Future trend: IP-based networks

Questions: Transition from existing networks to future IP-based networks
Architecture, protocols, migration



Development Scenario

Service and Technology Convergence



Ambient, Ubiquitous and Nomadic Communications

Ambient Communications

- Location and Context Awareness

  Examples: Location Based Services
  Context Aware Services

Ubiquitous Communications

- Distribution of Computer and Communication Functions in many devices ("smart its")

  Examples: Body (Personal) Area Networks
  Sensor / Actor Networks

Nomadic Communications

- Communication from any place including use of local / distant facilities

  Extension of the Mobile Communications Paradigm

New Mobile Services

Communication Services → Emerging Topics

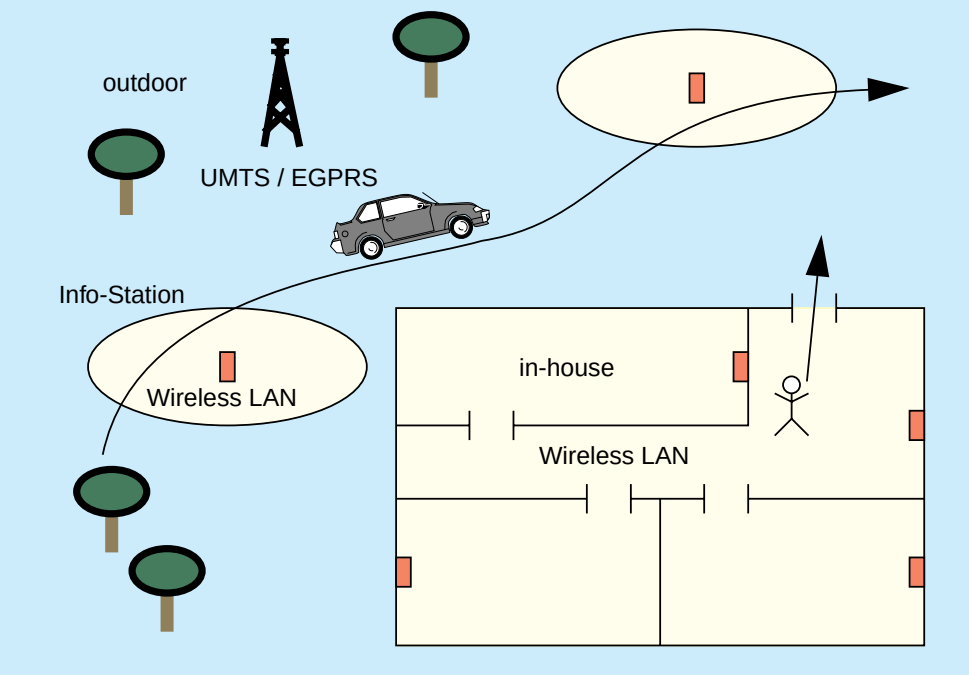
- **information services**
  - ➥ location/context aware services, navigation services, ...)
- **classical information services**
  - ➥ MMS, e-mail, ...
- **stream-oriented services**
  - ➥ speech and video telephony, ...

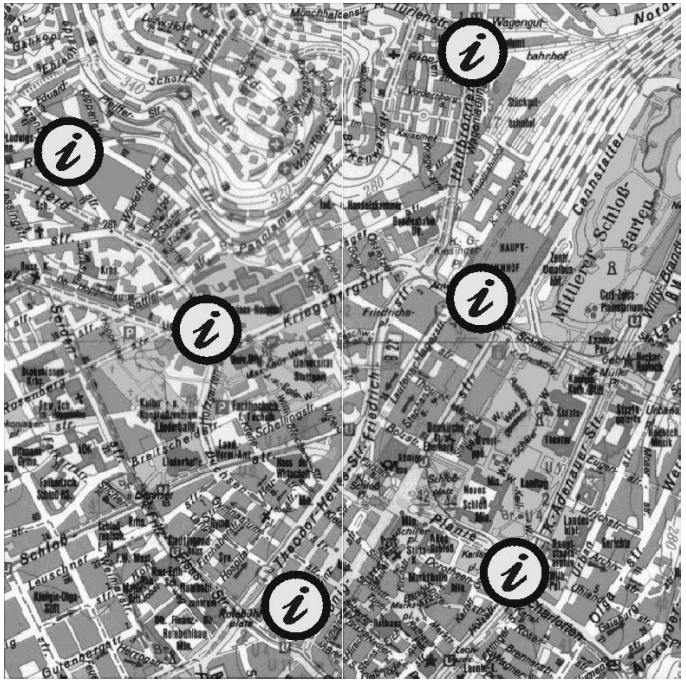
- **new services**
  - ➥ minimalistic user interface
- **new requirements to the networks**
  - ➥ mobility manangement/support
  - ➥ resource reservations
  - ➥ support for hundreds of niche applications
- **business models**

Communication Scenarios

Heterogeneous Access Networks

- **wireless network technologies are designed for special environments**
  ➥ e. g. indoor/outdoor, slow/fast users, low battery consumption, ...



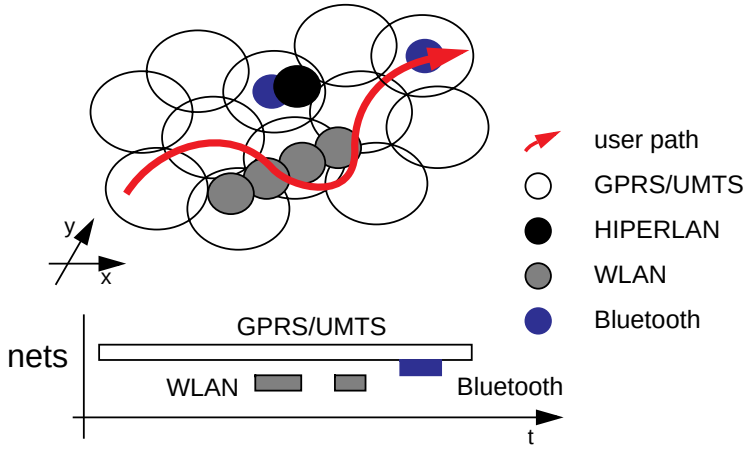


Quelle: U. Kubach (IPVR/AS), Universität Stuttgart, 2001

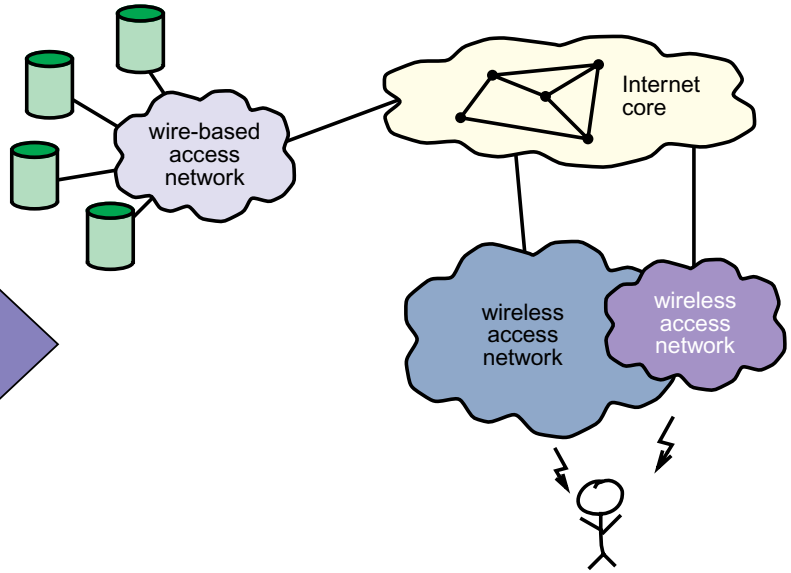
- **change of paradigm: from *anytime-anywhere* to *sometime-somewhere***
- **critical: network transitions in vertical direction**
- **users always want to use the best available network**
  - but without manual interactions
  ➥ research topic: Always Best Connected (ABC)

Challenge: Adaptation of Networks and Applications

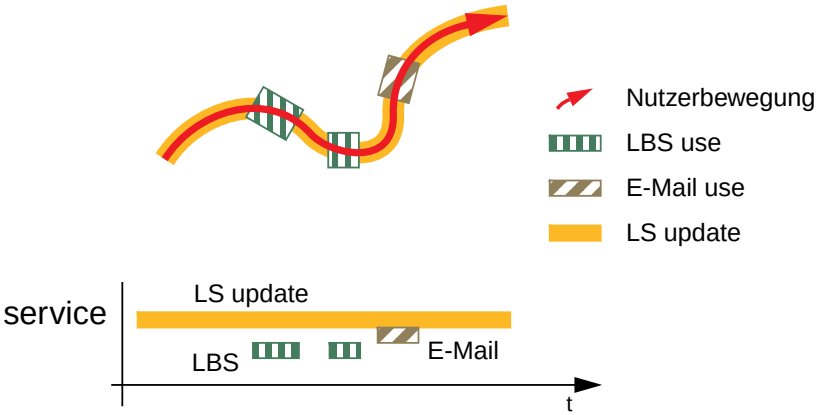
network availabilities



- **inter-technology mobility support**
- **abstraction of networks and technologies**



user requirements (user view)



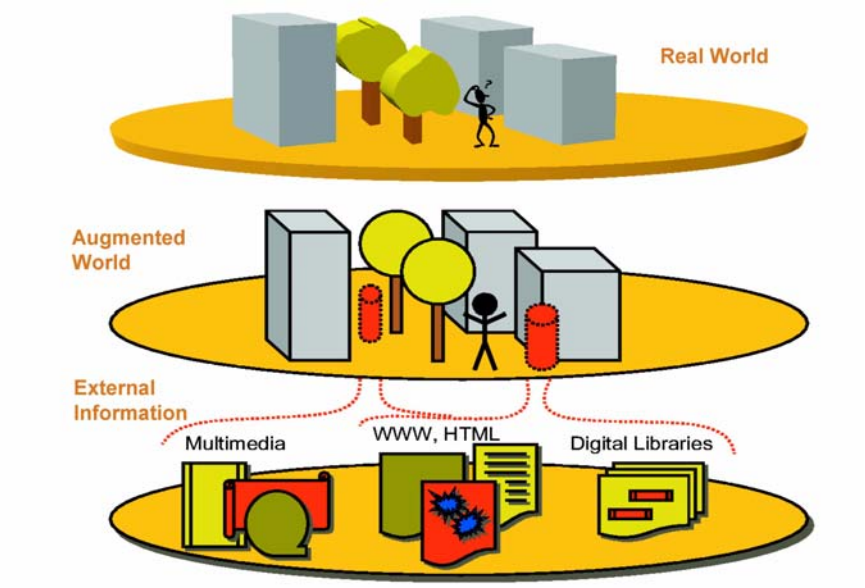
- **fair and adequate resource sharing**
- **control of communication costs**

Project Aims (Interdisciplinary)

- **platform for the support of context-aware services**

  ➥ open system platform

- **"world model" for context aware systems**



Quelle: IPVR/VS, Universität Stuttgart, 1999

- **technology assessment**

  ➥ security and privacy aspects, social acceptance, ...

- **applications**

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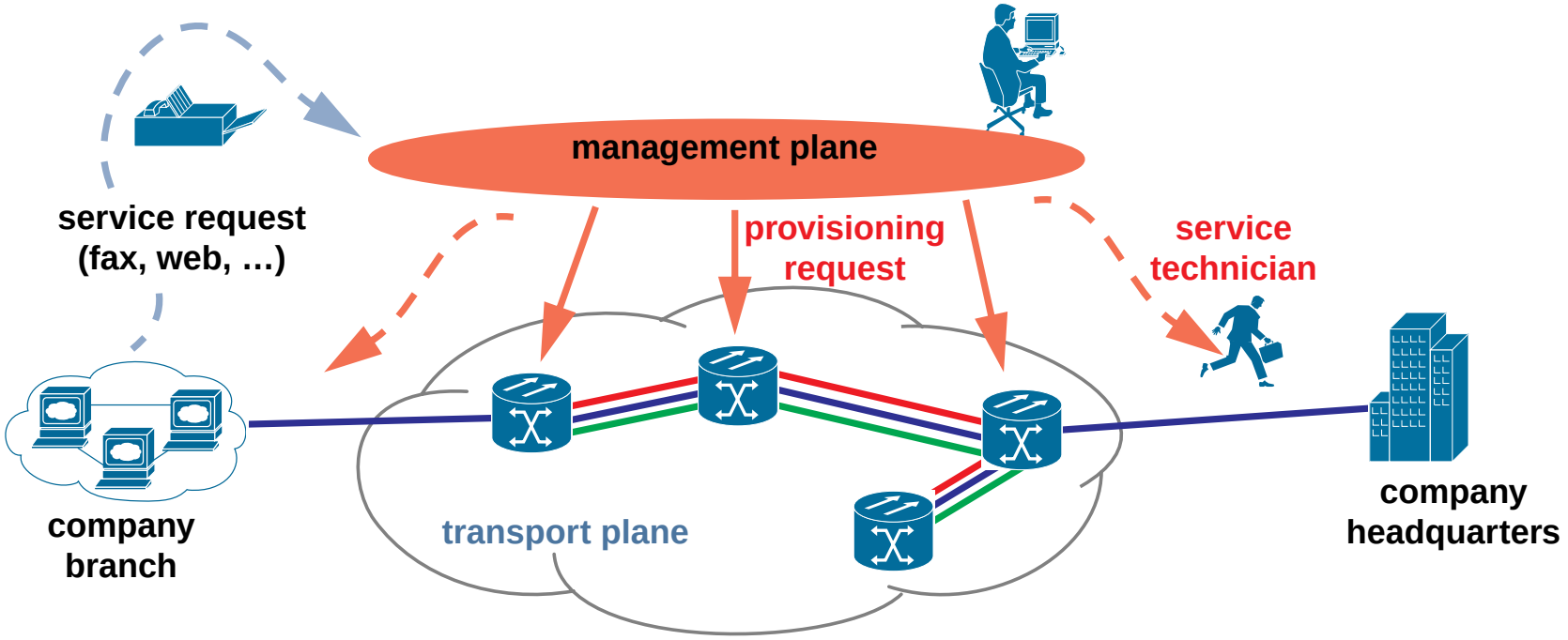
Technical Challenges of NGN

Topics	Examples
1. Architectures and Platforms	• Control of Dynamic Transport Networks • Optical Burst Switching • NGN Service Platforms
2. Quality of Services and Traffic Engineering	• Traditional Solutions • QoS in the Internet
3. Communication & Security	• Architectures and Protocols • Mobility • Security and Privacy

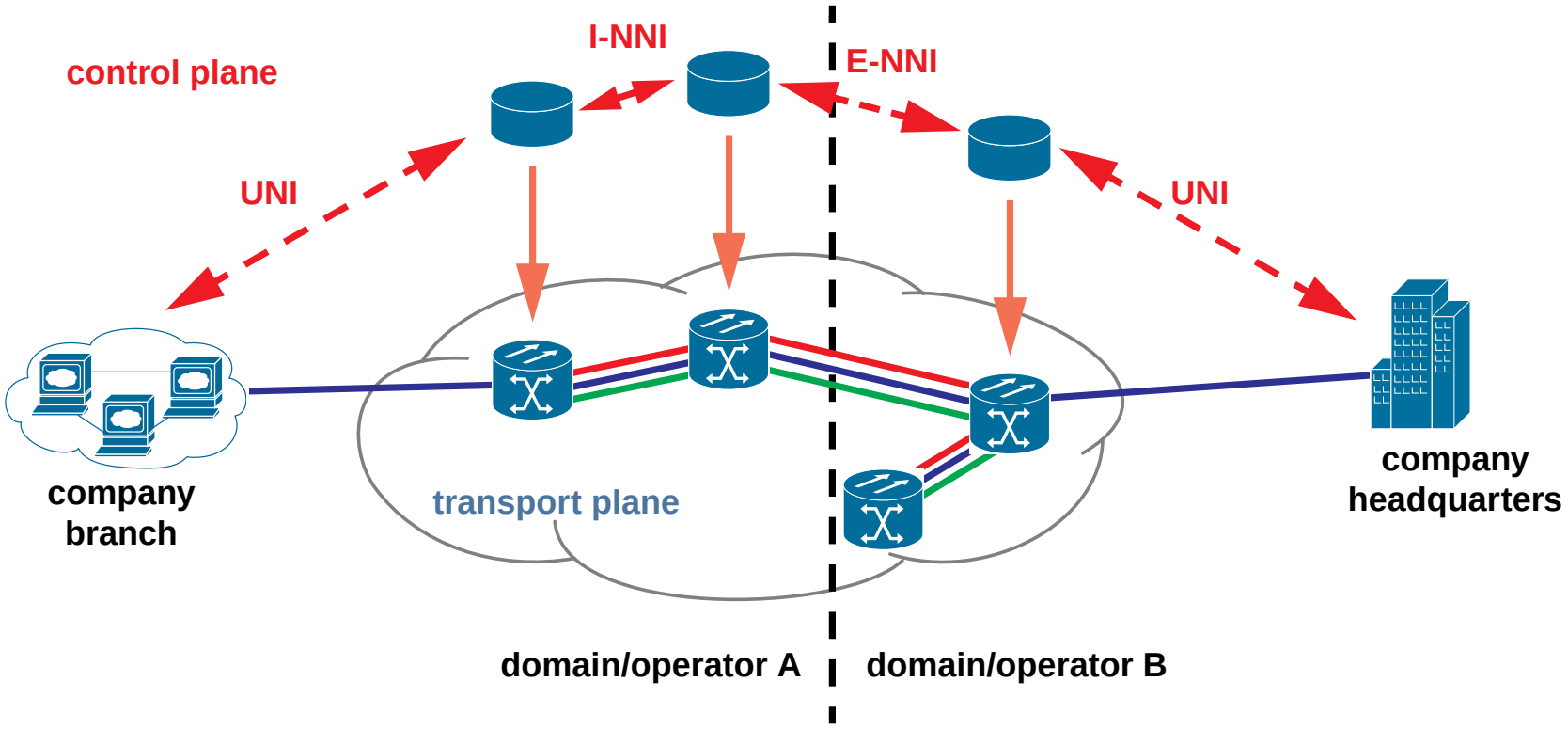
ASTN Functionality

- **Provisioned/hard permanent connection (PC)**
  - controlled by management system
  - long provisioning times

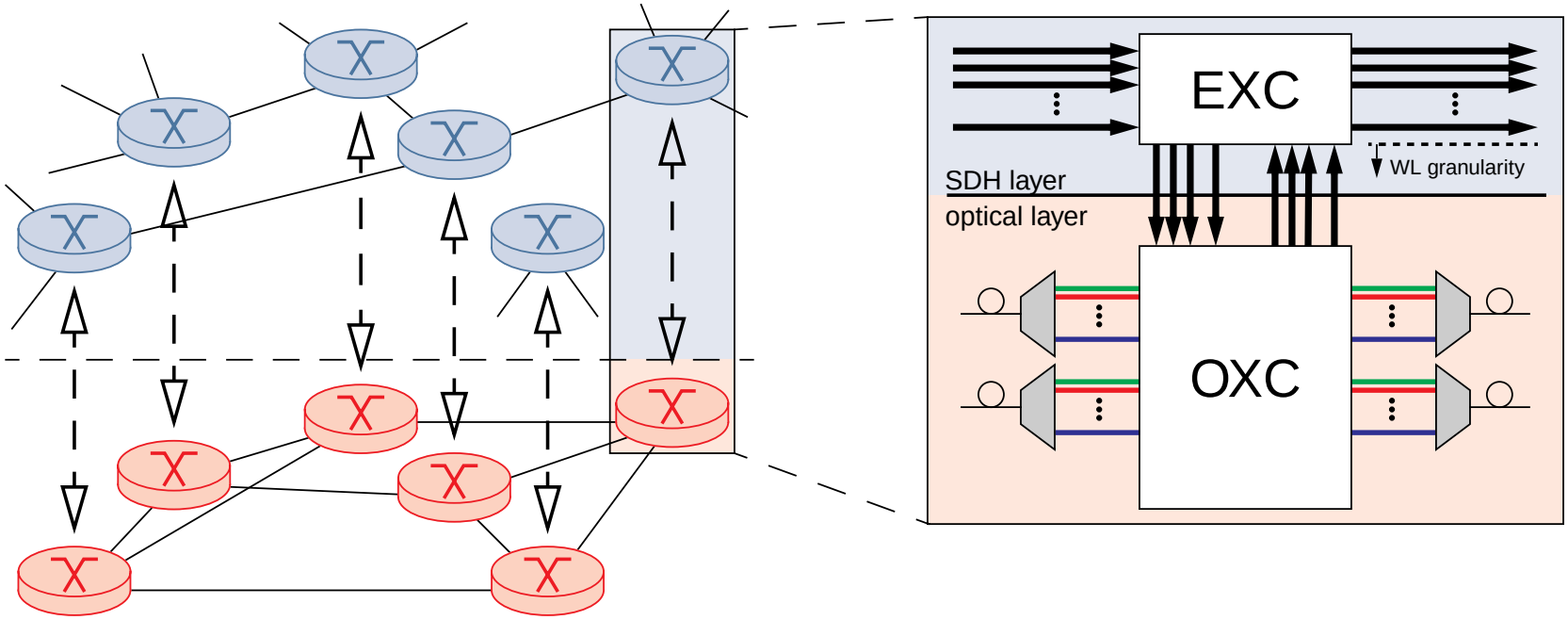


ASTN Functionality

- **Switched connection (SC)**
  - uses control plane with user-network-interface (UNI) and internal/external network-network-interface (I-NNI/E-NNI)
  - dynamic information exchange
- **Soft permanent connection: SC only within network, no UNI**

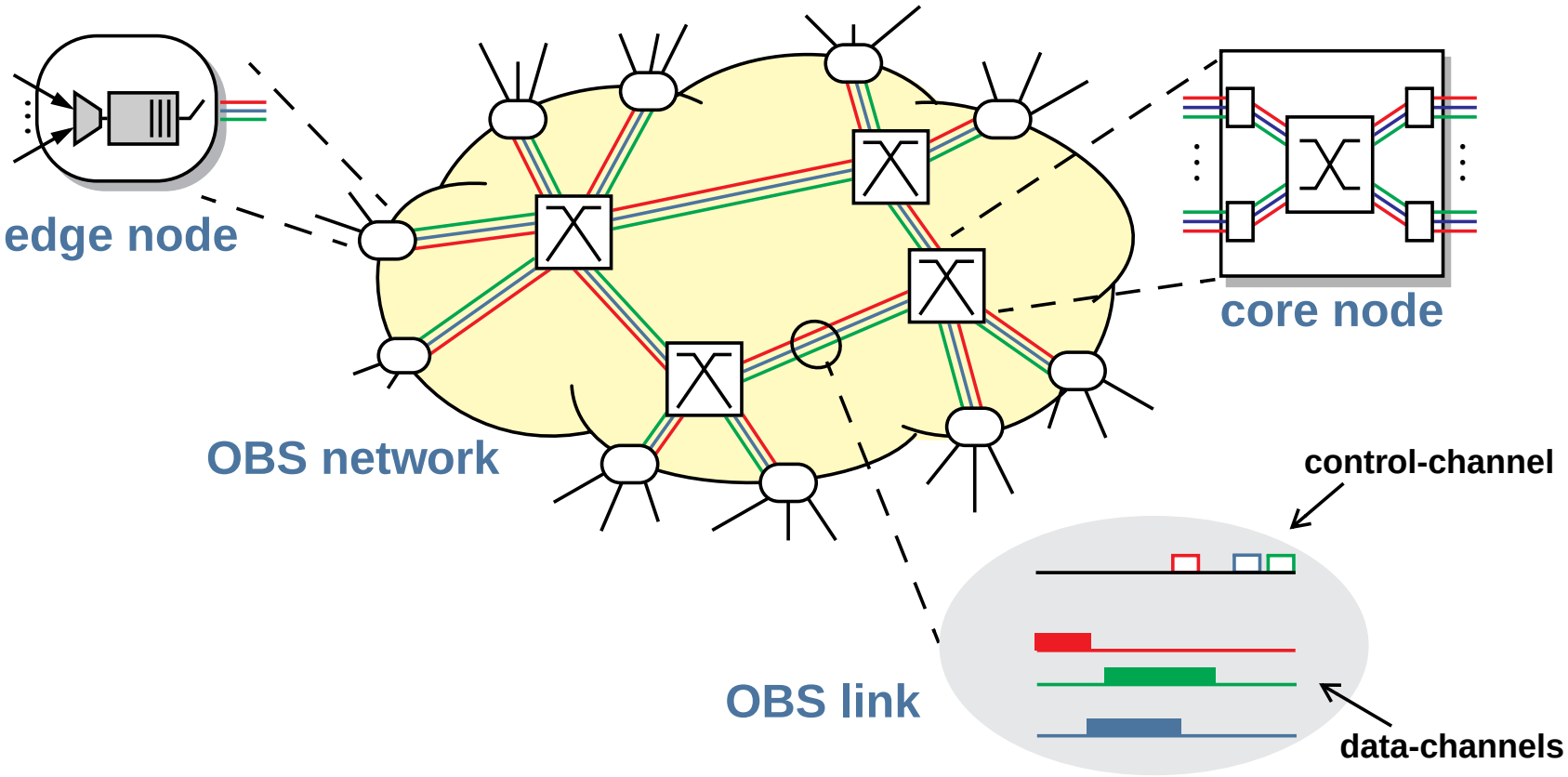


Multilayer Networks - Architecture



- **Circuit switched transport network**
- **Evolutionary extension of current core networks**
- **Optimal combination of**
  - optical transport
  - electronic aggregation and traffic engineering

Optical Burst Switching



- **Burst assembly in edge node, mostly variable length**
- **WDM-based transmission**
- **Separation of control and data**
- ***Fast* optical switch**
- **Separation of control and data**

Contention Resolution in OBS

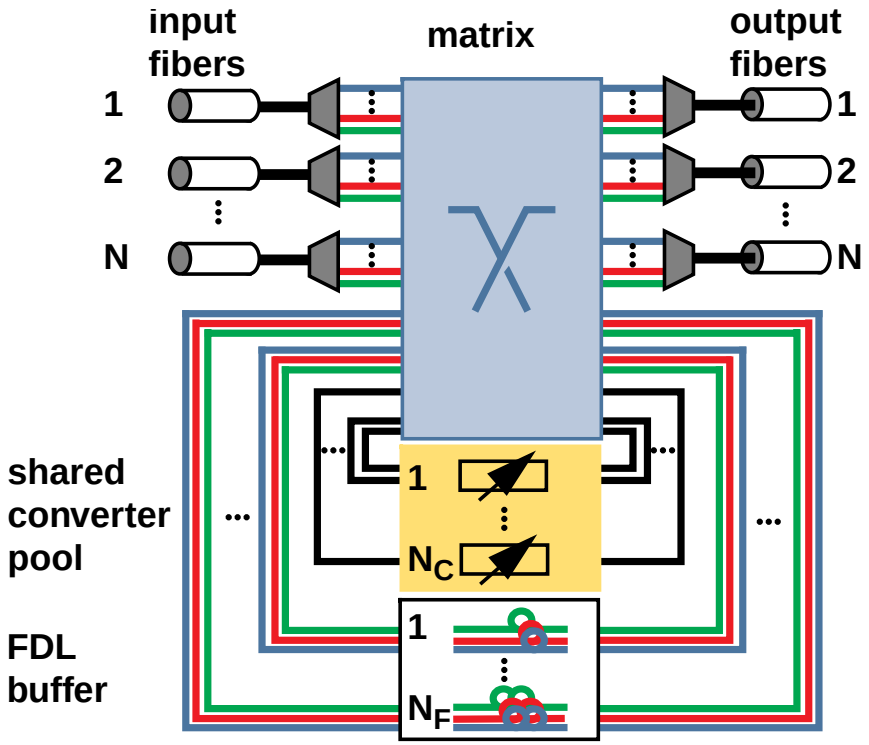
- **Burst loss possible due to bufferless statistical multiplexing**
- **Application of OBS in high-speed metro/core networks**
  - ➥ lost data has to be retransmitted on end-to-end basis not locally
  - ➥ very low burst loss probability required (e.g., 10^{-6})

➥ **Need for highly effective contention resolution**

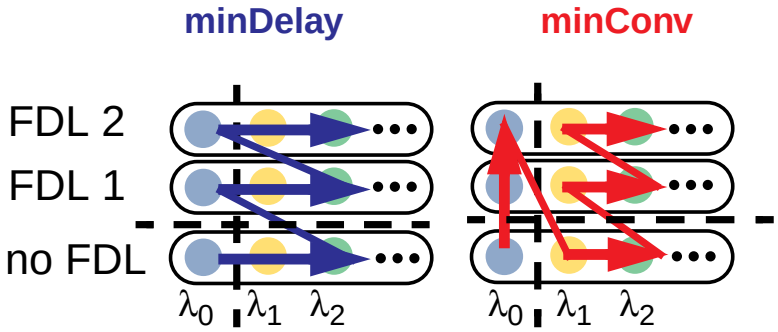
- **Wavelength domain** **wavelength conversion**
  - very effective as all WDM channels shared among all bursts
  - but: low burst loss probabilities only for $\geq 100\,\lambda$s
  - ➥ additional schemes necessary
- **Time domain** **fiber delay lines (FDLs)**
- **Space domain** **deflection/alternative routing**

➥ **Optimized combination of these schemes**

Contention Resolution in OBS

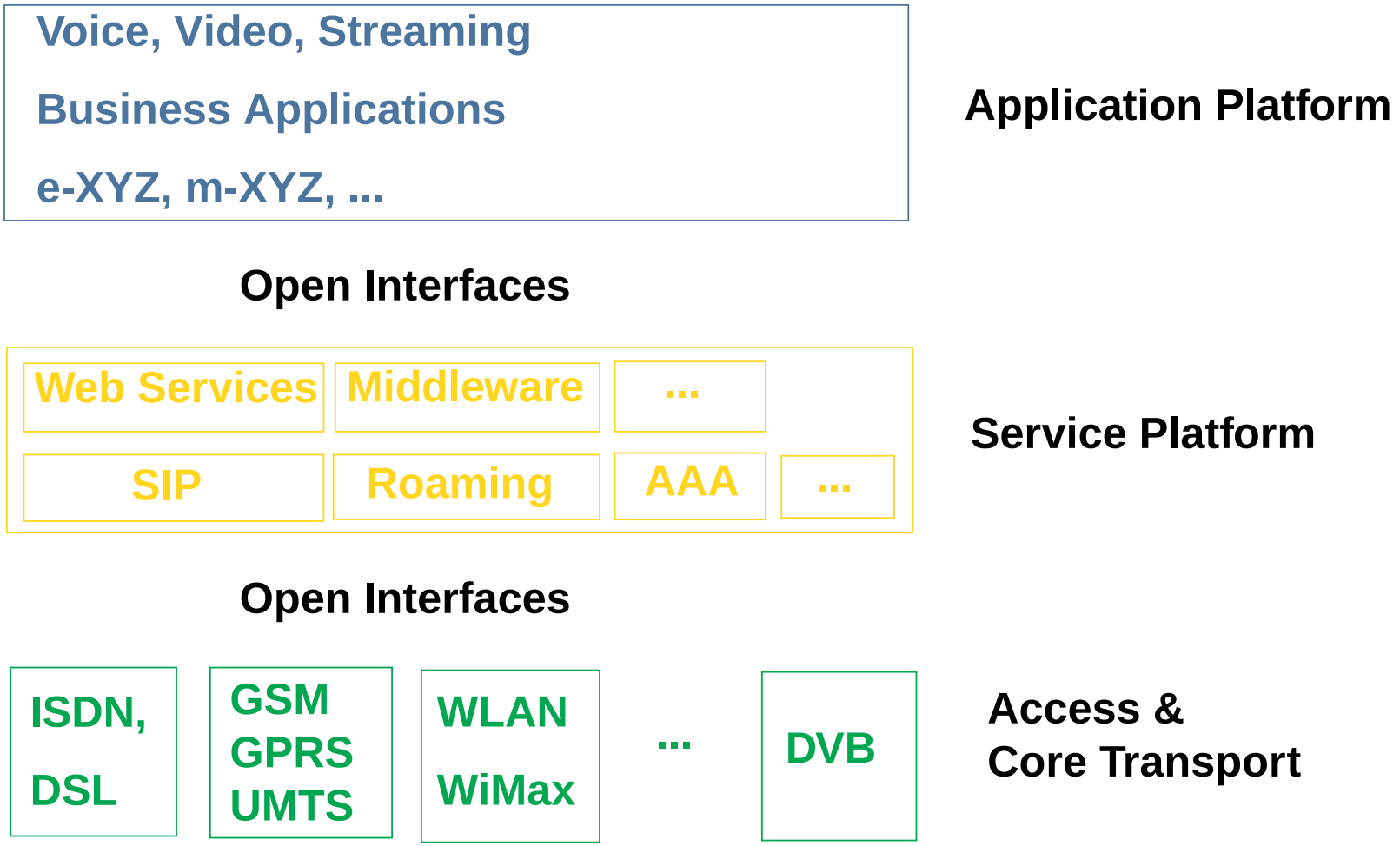


Selection strategies for converter and FDLs



- **Potential for resource/performance optimization in OBS node**
- **Different selection strategies for converters and FDLs**
  - minDelay minimizes delay at cost of higher converter usage
  - minConv minimizes converter usage at cost of higher delays

NGN Service Platforms

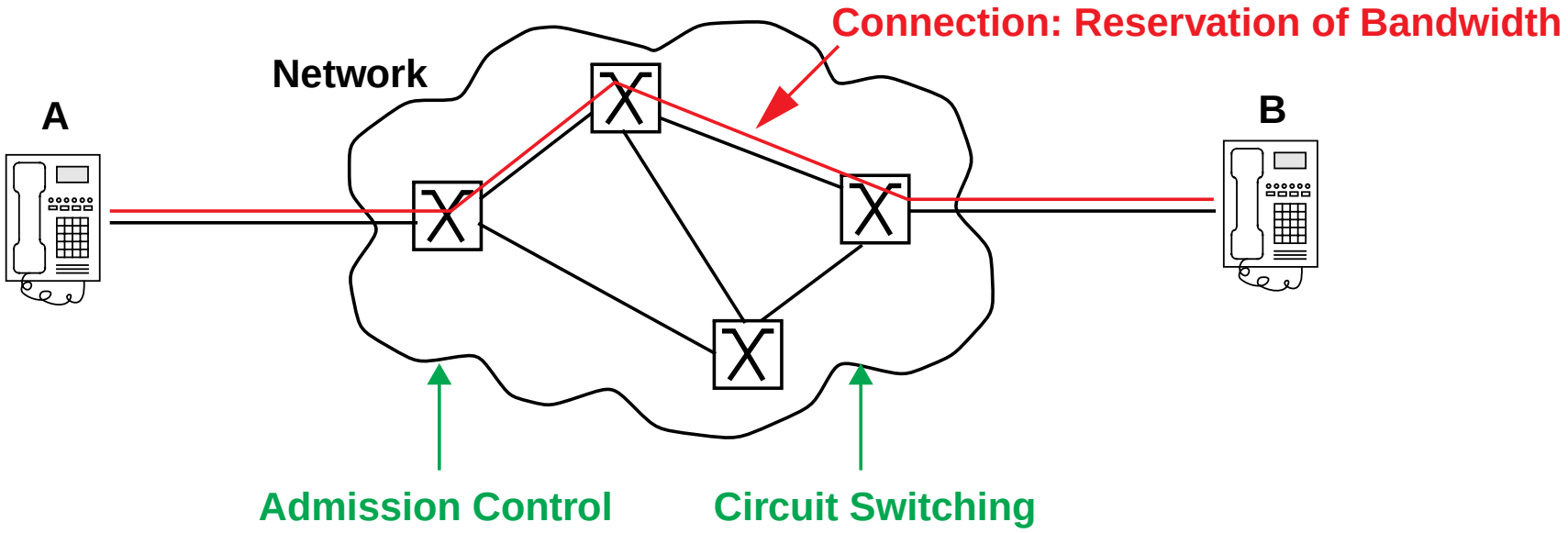


Technical Challenges of NGN

Topics	Examples
1. Architectures and Platforms	• Control of Dynamic Transport Networks • Optical Burst Switching • NGN Service Platforms
2. Quality of Services and Traffic Engineering	• Traditional Solutions • QoS in the Internet
3. Communication & Security	• Architectures and Protocols • Mobility • Security and Privacy

Traditional Solutions

Example 1: Telecommunication Services

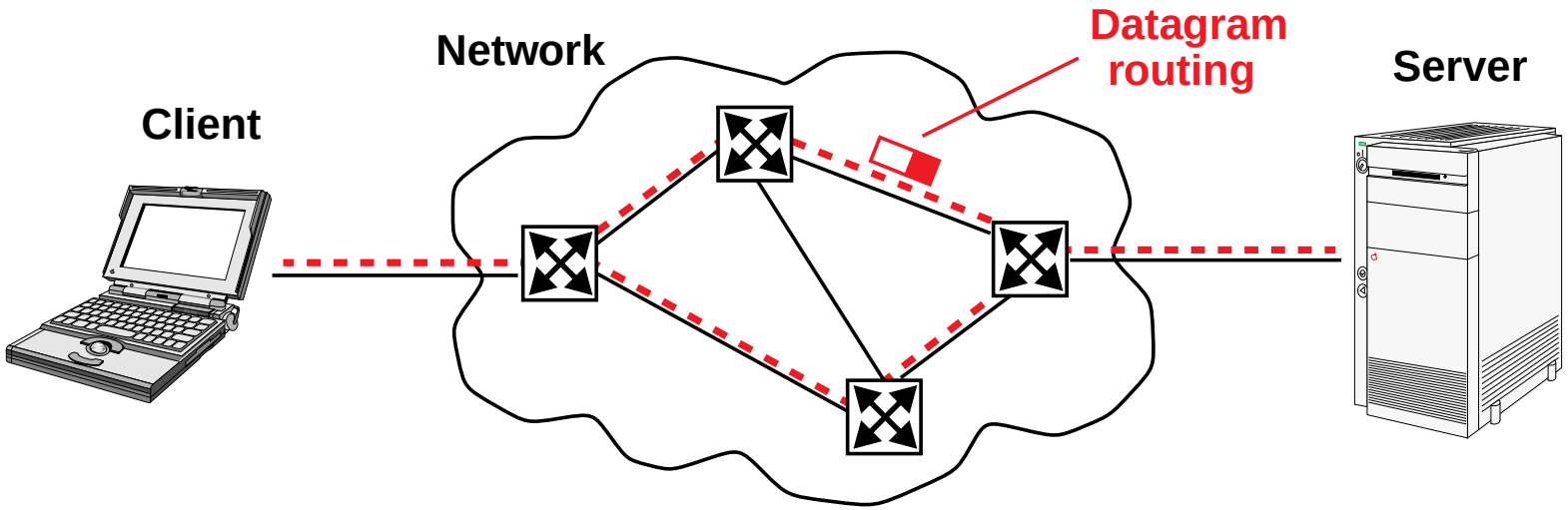


Traditional Solution is not feasible for many new applications due to:

- **Variable bitrate sources (burst traffic)**
- **Overhead for connection management (delay, state management, ...)**
- **Integration of many services with quite different characteristics**
- **Inflexibility with respect to adaptation to application requirements**
- **Cost**

Traditional Solutions

Example 2: Internet

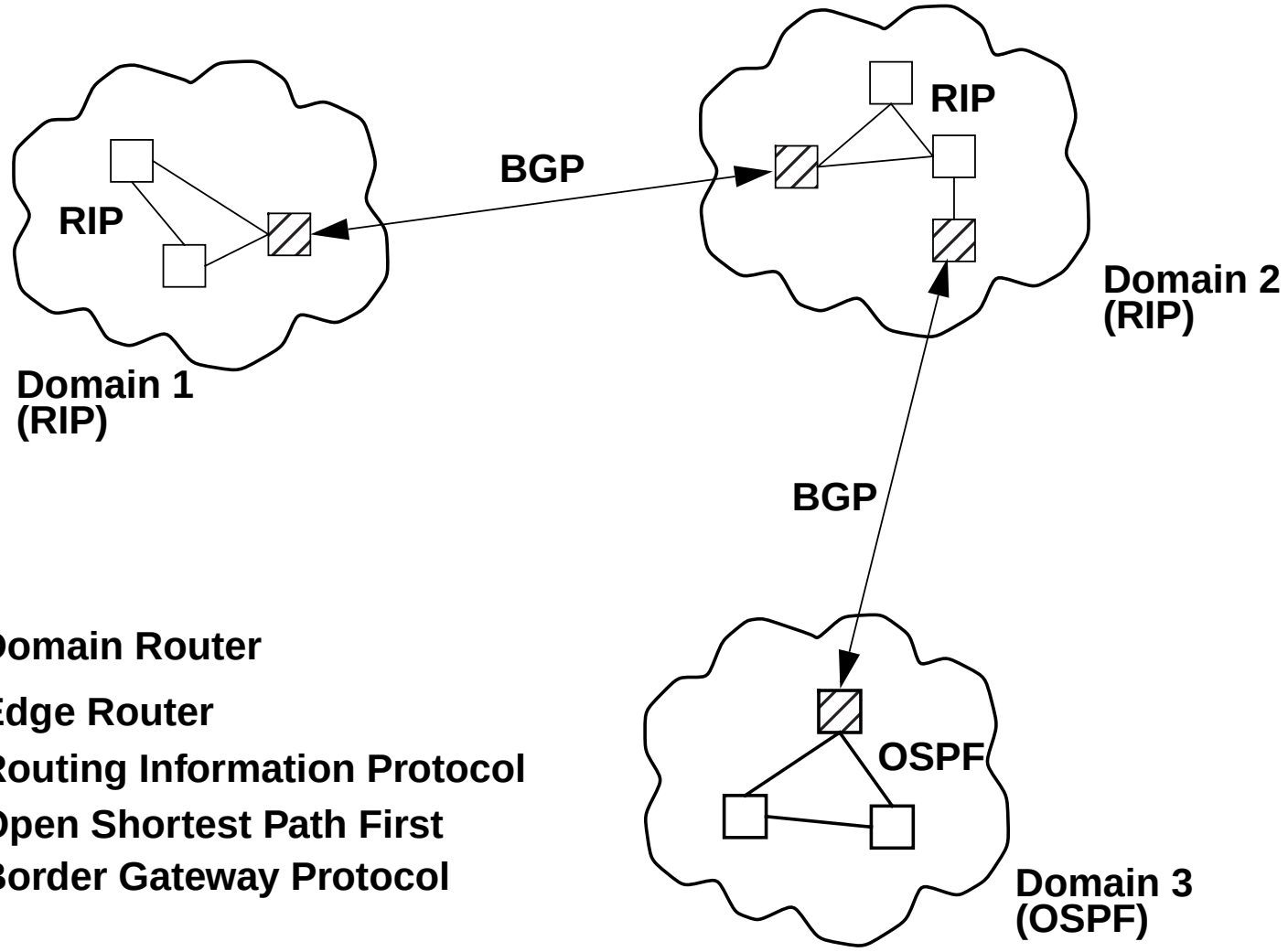


"Best Effort Service": **No admission control**
No resource reservation
Unpredictable delays and losses

BES is not feasible for many new applications due to:

- **No guarantees on QoS**

Internet Routing



	Domain Router
	Edge Router
RIP	Routing Information Protocol
OSPF	Open Shortest Path First
BGP	Border Gateway Protocol

QoS Management in the Internet

Traffic Classes in the IntServ-Model

- **Guaranteed Service** **(similar to CBR and rt-VBR)**
- **Controlled Load Service** **(similar to nrt-VBR)**
- **Best Effort Service** **(similar to UBR)**

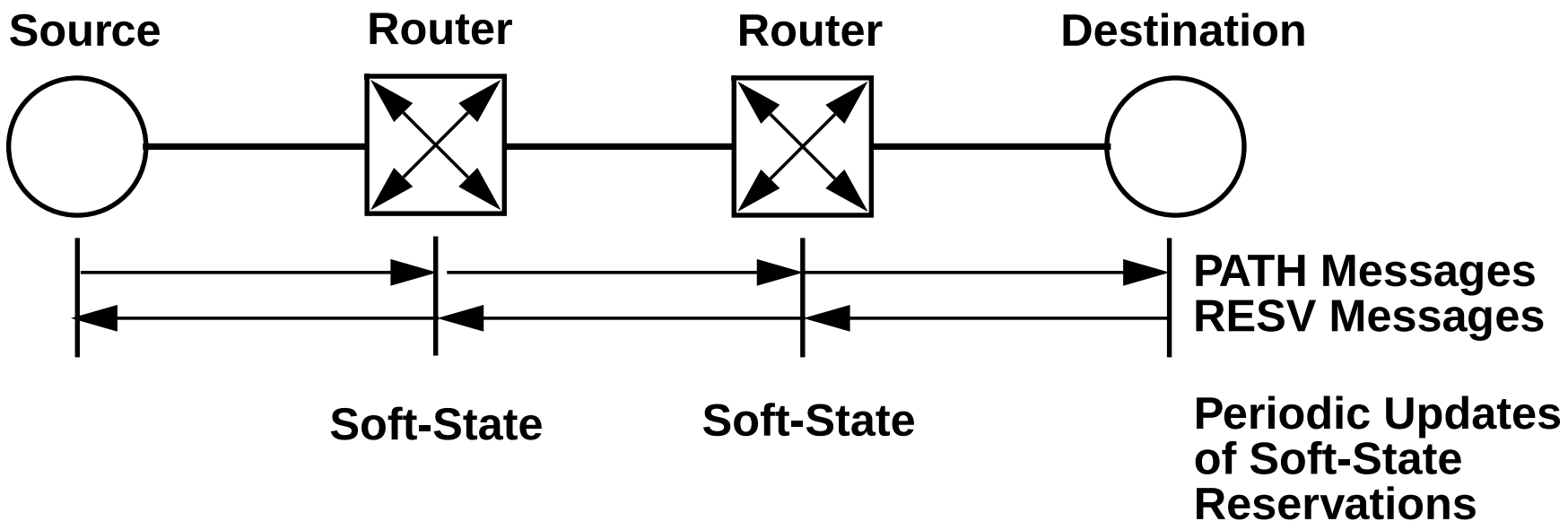
Use of RSVP

Traffic Classes in the DiffServ-Model

- **Expedited Forwarding** **(Premium Service)**
- **Assured Forwarding with different Priorities**

Hop-by-Hop Control

IntServ-Model



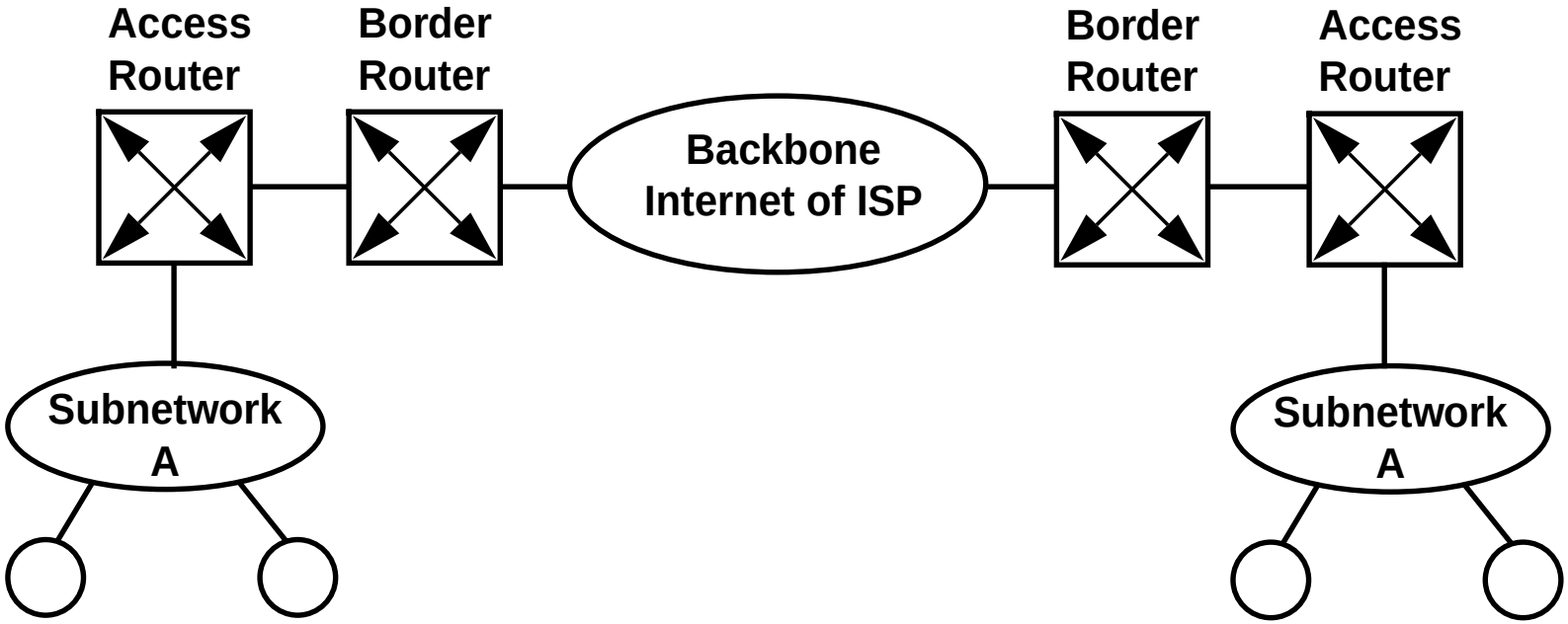
Flow Description by

Flow Specifications (FlowSpec)

- **Service Class**
- **Reserve Specification (RSpec)**
- **Traffic Specification (TSpec)**

Filter Specification (FilterSpec)

DiffServ Model



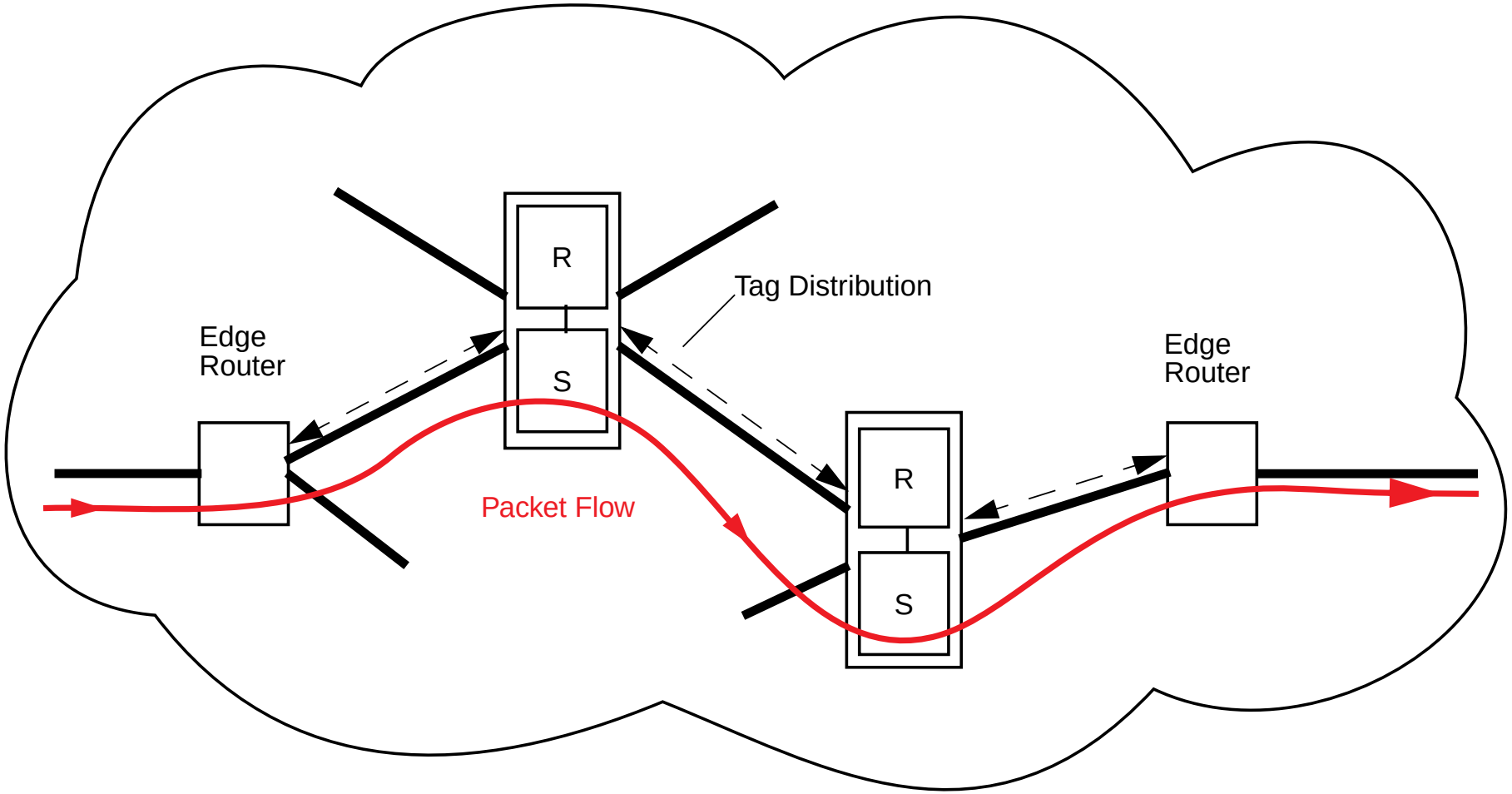
Negotiation of max. Bitrate between User and ISP for Aggregated Traffic Volumes
Classification of Traffic Class by Access Routers

Premium Service: Separate Queues and Prioritized Transport provide virtual leased Line Service
Policing Function by Border Router

Assured Service: Use of Priority to provide QoS for short Bursts
Policing Function and Packet Dropping by Border Router
Appropriate Dimensioning of Transmission Resources by ISP

Per Hop Behaviour (PHB) Routing, Marking of IP Packets within DS-Field

Tag Switching



- **Detection of flows**
- **Assignment of flow labels**
- **Fast switching along pathes**

→ **State-based switching**

Challenges of NG Internet with Respect to QOS

- **Tremendous increase in bandwidth demand in mobile and fixed networks for new applications**
  Ahead: Japan and Rep. of Korea (70/60 % mobile Internet users;
  US/Europe < 10%)
  Asia-Pacific Region leading in broadband penetration
- **Rapid decrease of internat. bandw. pricing from 111 TUSD (1998) to 10 TUSD (2002) for US-Japan 1Mbps link per year**
- **NG Internet Technology and broadband access**
- **Fast routing algorithms**
- **Convergence of Internet and Mobility**
- **Adaptive traffic control (e.g., for Peer-to-Peer applications)**
- **Negotiable QoS Levels and QoS guarantees**
- **Accounting and charging for highly variable bitrate services**
- **Ubiquitous computing and ad hoc communication networks**
- **Adaptation of source coding and network traffic control**
- **QoS across multiple layers and heterogeneous network technologies**

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2. Quality of Services and Traffic Engineering	• Traditional Solutions • QoS in the Internet
3. Communication & Security	• Architectures and Protocols • Mobility • Security and Privacy

Research Topics - Communication & Security

Architectures & Protocols

- **Unified Communication based on IPv6**
- **Communication across different Networks**
- **Mobility Management based on Mobile IP Concepts**
- **Dynamic Address Management**
- **Horizontal and Vertical Handover**
- **Integration of Ad Hoc Networks (infrastructureless)**
- **Middleware Concepts**
  Abstraction from Underlying Network Infrastructures
- **Design & Implementation**
- **Standardization**

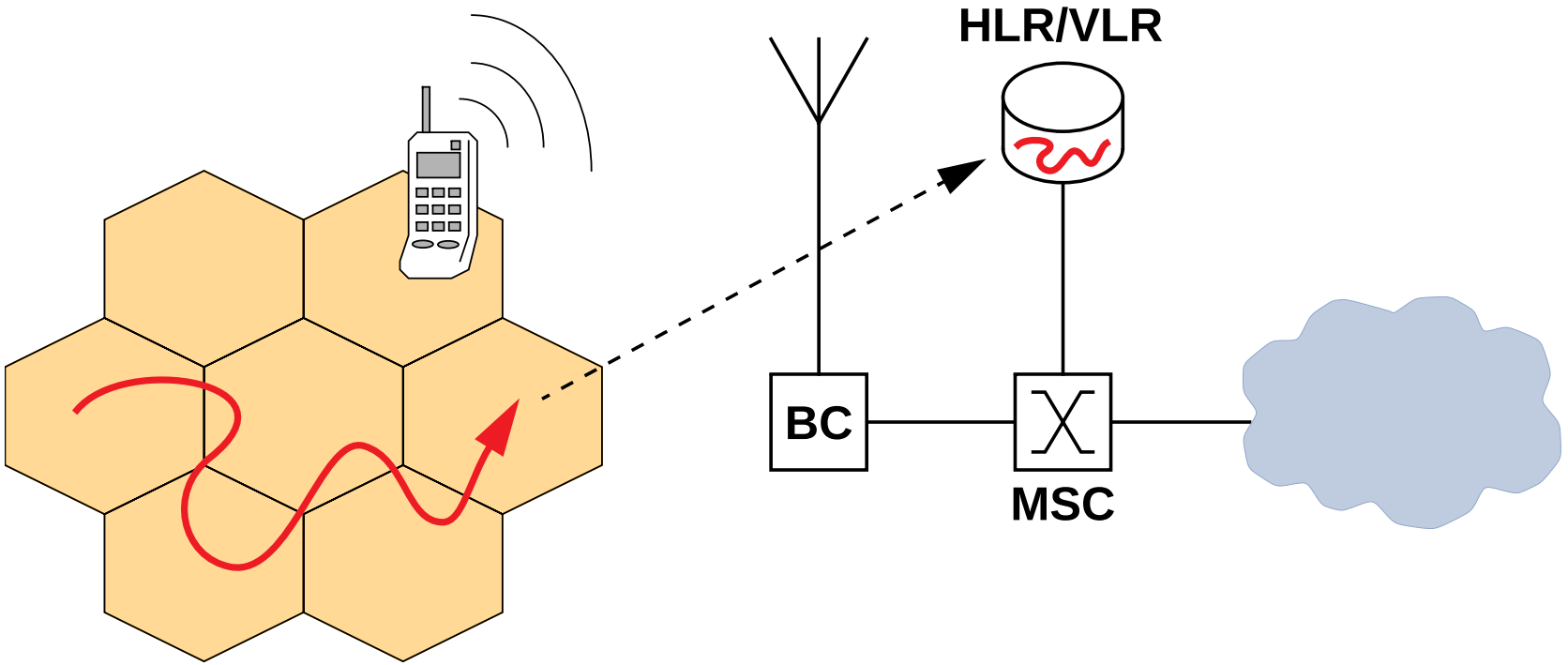
Research Topics - Communication & Security

Mobility

- **Modelling of Mobility of Users and Data**
- **Modelling of (Communication) Traffic**
  -spatial and temporal
- **Disconnected Operation (information Caching and Fuelling)**
- **Predictive Information Provision (Hoarding)**
- **Simulation Methods for Mobility**
- **Performance**

Research Topics - Security & Privacy

Example



- **Tracking of Location May Cause Severe Privacy Problems**
- **Similar Problems Arise from Recording of User Activities**

Research Topics - Security & Privacy

- **Protection Against Concatenation between Location Data and User Identity**

- **Methods:**
  - Pseudonymization
  - Authentication
  - Multilateral Security concepts:
    Negotiation of Protection Aims and Strengths
  - Accountability and Non-Repudiation
  - Integrity

- **Security Protocol Design**

Conclusion (1): General Observations

- **Change of Paradigms in the Communication Sector**
  - heterogeneous network technologies, broad spectrum of applications
  - trend directs to IP-based network and transport protocols
  - technology push and market pull
- **Success Factors**
  - time to market
  - open platforms
  - user acceptance
- **Design Processes**
  - limited development periods
  - specialization and limitation to core competences ("make or buy?")
  - design automation, design platforms and tools
- **Standardization and Quality**
  - proprietary solutions vs. open platforms
  - need for standardization
  - product quality and quality of service

Conclusion (2): Research Areas

- **Integration of the various Network Technologies**
  - fixed, mobile and ad hoc networks
  - internet and photonic technologies
  - support of autoconfiguration and manageability
- **Platforms**
  - advanced middleware concepts
  - service creation support
  - application programming interfaces
- **New Application Paradigms**
  - location and context based services
  - nomadic communications and ubiquitious computing
  - overlay networks
- **New Business Models**
  - micropayment
  - quality of service
  - scalable security