Development of Global Communications

- The Path Towards an All-Embracing Information Infrastructure -

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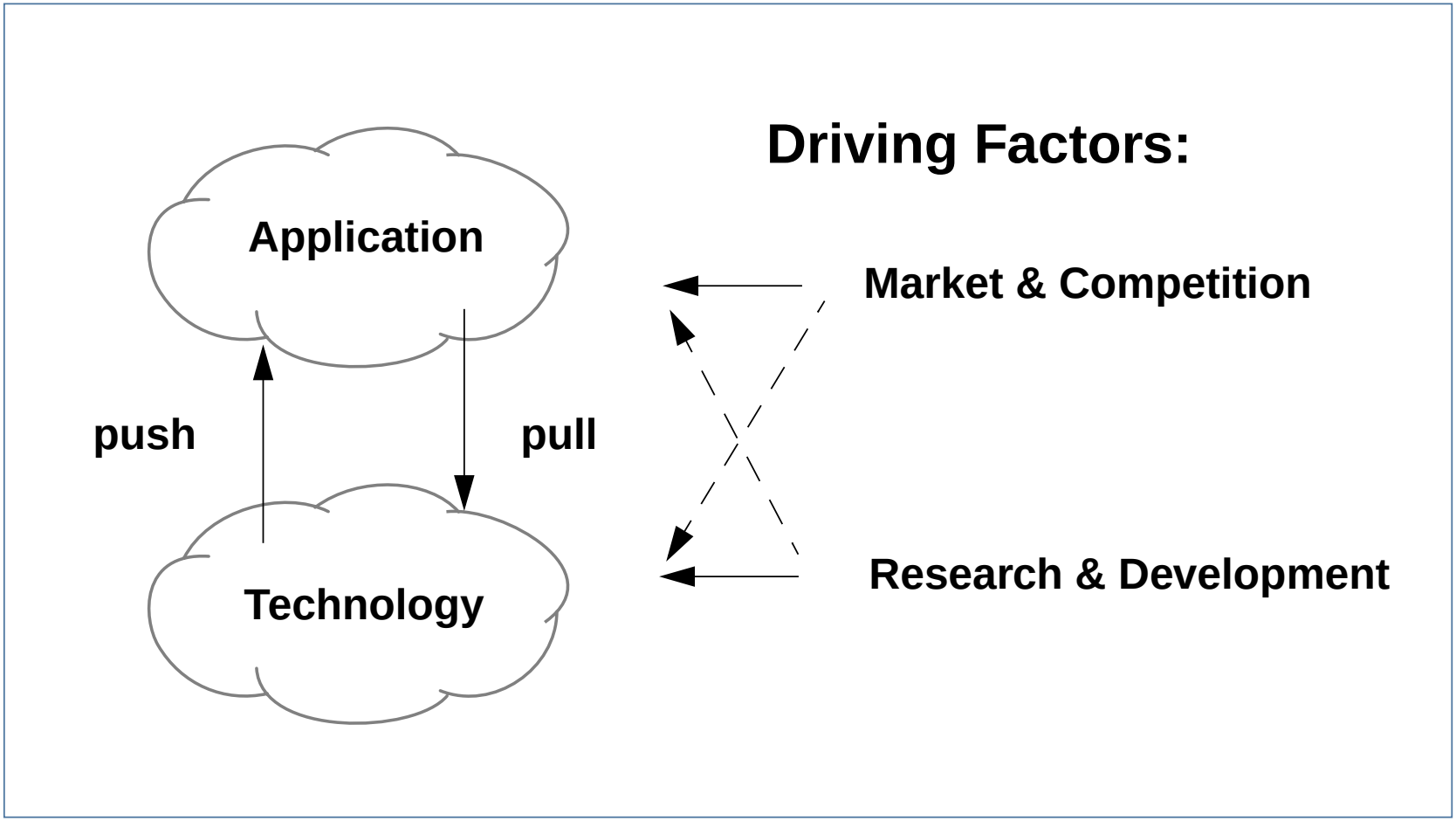
The Innovation Process



Developments of Global Communications

1. Component Developments
2. Development of Networks
3. Development of Services and Applications
4. Problems and Challenges

1. Component Developments (1)

- **Microelectronics**

VLSI-Technology (CMOS)	**2006:**	**200 nm**
	2010:	**100 nm**
	2020:	**50 nm**

Production Costs

Microprocessors	**2006:**	**500 ps clock period**
	2010:	**250 ps**
	2020:	**100 ps**
Memory Technology	**2006:**	**L1 Cache 64 kByte**
		L2 Cache 2 MByte
		RAM 8 GByte, 40 ns access time
		Disk 1 TByte, 5 ms access time
		Tape > 1 TByte, > 1s access time
Display Technology	**today: Thin Film Transistor Technology**	
	future: Organic Light Emitting Diodes (OLED)	

1. Component Developments (2)

- **Computer Hardware:** **RISC Microprocessor Components with Pipelining and Caches**
  Microcontrollers for Device Control
  Signal Processors
  Network Processors
  Programmable Logic Arrays
  VLSI Highlevel Description Languages (VHDL)
  Configurable Hardware
- **Embedded Systems** **Hardware/Software Co-Design**
  Real Time Control
- **Sensors** **RFID Passive Devices**
  Sensor Devices (Processor, RF Antenna, Power)

1. Component Developments (3)

- **Software-Languages**
  - **Object-Oriented Languages (Java, Ada, ...)**
  - **High Level Description Languages (XML)**
  - **Web Description Language (WDSL)**
  - **Database Access Language (SQL)**
- **Software Design**
  - **Reusability, Inheritage**
  - **Design Pattern**
  - **Component Software**

1. Component Developments (4)

- **Transmission**

  Electrical Wire: TP, STP, Coaxial

  Optical Fibre: **Fibre Optic** **Multimode**
  Monomode 10 ... 40 Gbps
  Plastic Fibre

  Wave Length Division Multiplex (WDM)
  Degree 80 ... 100
  ≥ 1 Terabit/s on one fibre

  Optical Components (Splitter, Amplifier, ...)

  Infrared (IR): **Short Range Wireless Communication**

  Microwave: **Short/Long Range Wireless Communication**
  Phased Array Antenna Systems
  Multiple Input, Multiple Output (MIMO) Systems

1. Component Developments (5)

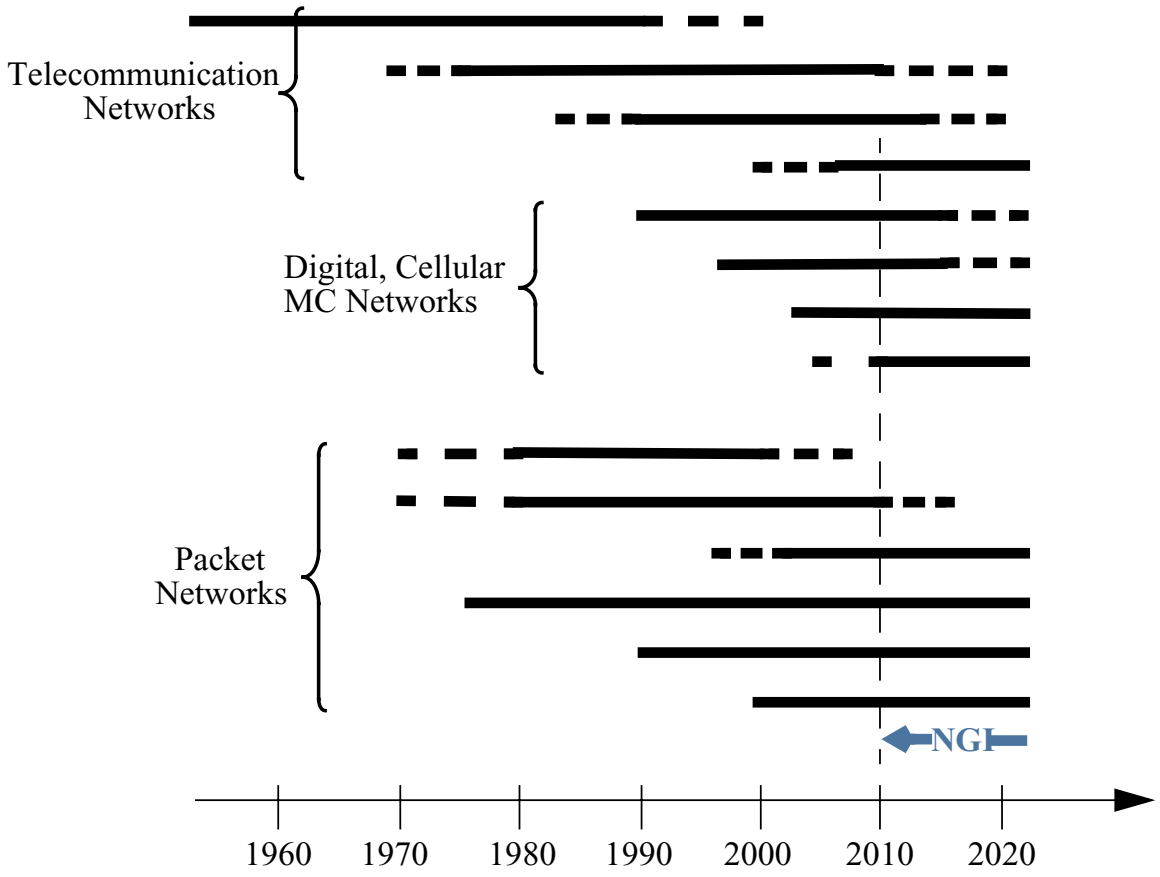
- **Switches**
  - **ATM Cell Switches**
  - **Frame Switches (Layer-2-Switches)**
  - **Optical SDM Switches (Micromirrors, SOA)**
  - **Optical WDM Switches w/wo Wavelength Conversion**
  - **Optical Burst Switching**
  - **(Optical Packet Switching)**

- **Routers**
  - **IP Packet Routers with**
  - **Packet Classification**
  - **Switching Fabric**
  - **Router Unit**
  - **Traffic Shaping**
  - **Buffer Management**
  - **Admission Control**
  - **Multiprotocol Label Switching (MPLS)**
  - **...**

2. Development of Networks

1. Development of Network Technologies
2. Fixed and Mobile Telecommunication Networks
3. Computer Communication Networks
4. Backbone and Access Networks
5. Network Convergence
6. Horizontal and Vertical Integration
7. Service and Technology Convergence
8. Ambient, Ubiquitous and Nomadic Communication
9. ASTN Developments
10. Multilayer Network Architectures

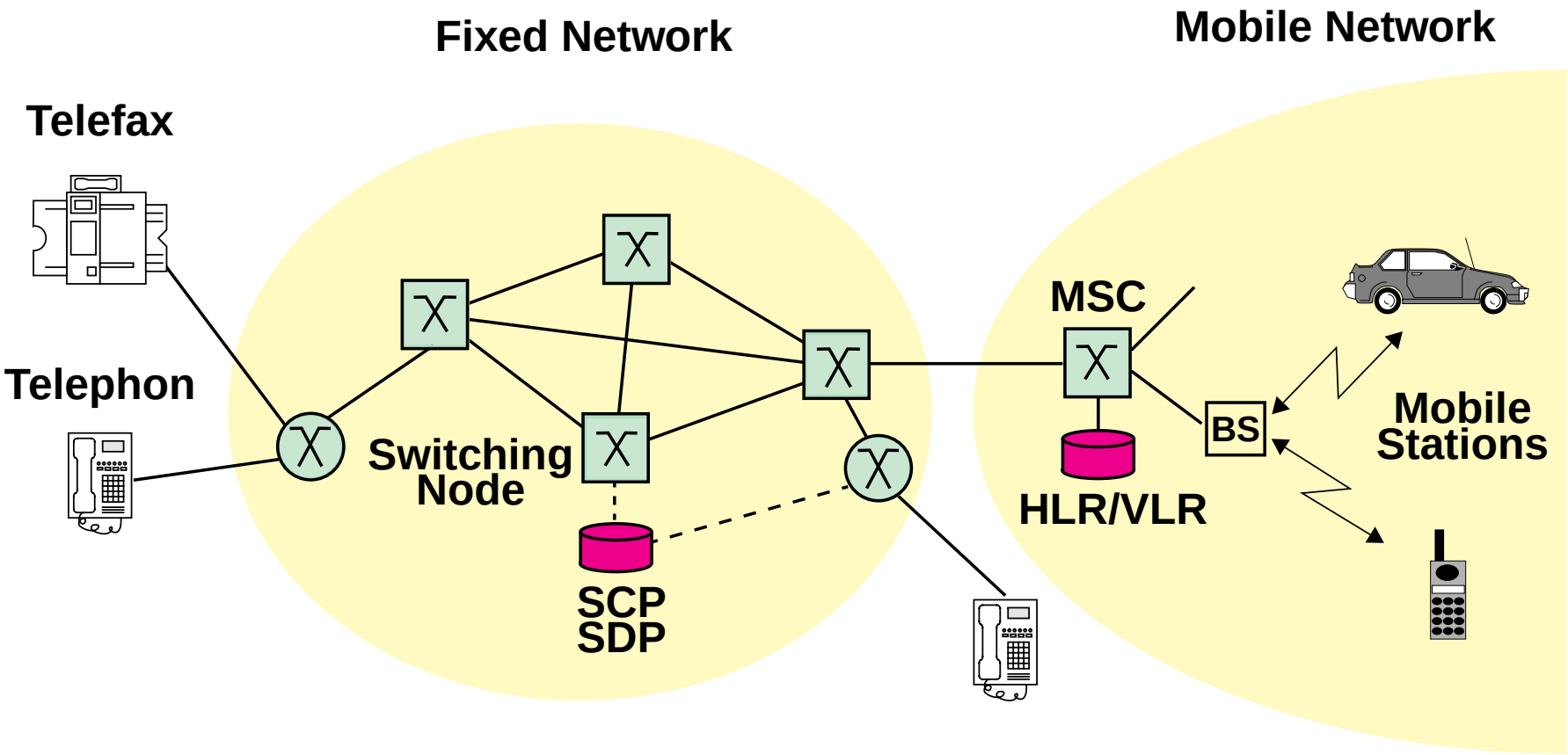
2.1 Development of Network Technologies



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 Netw.

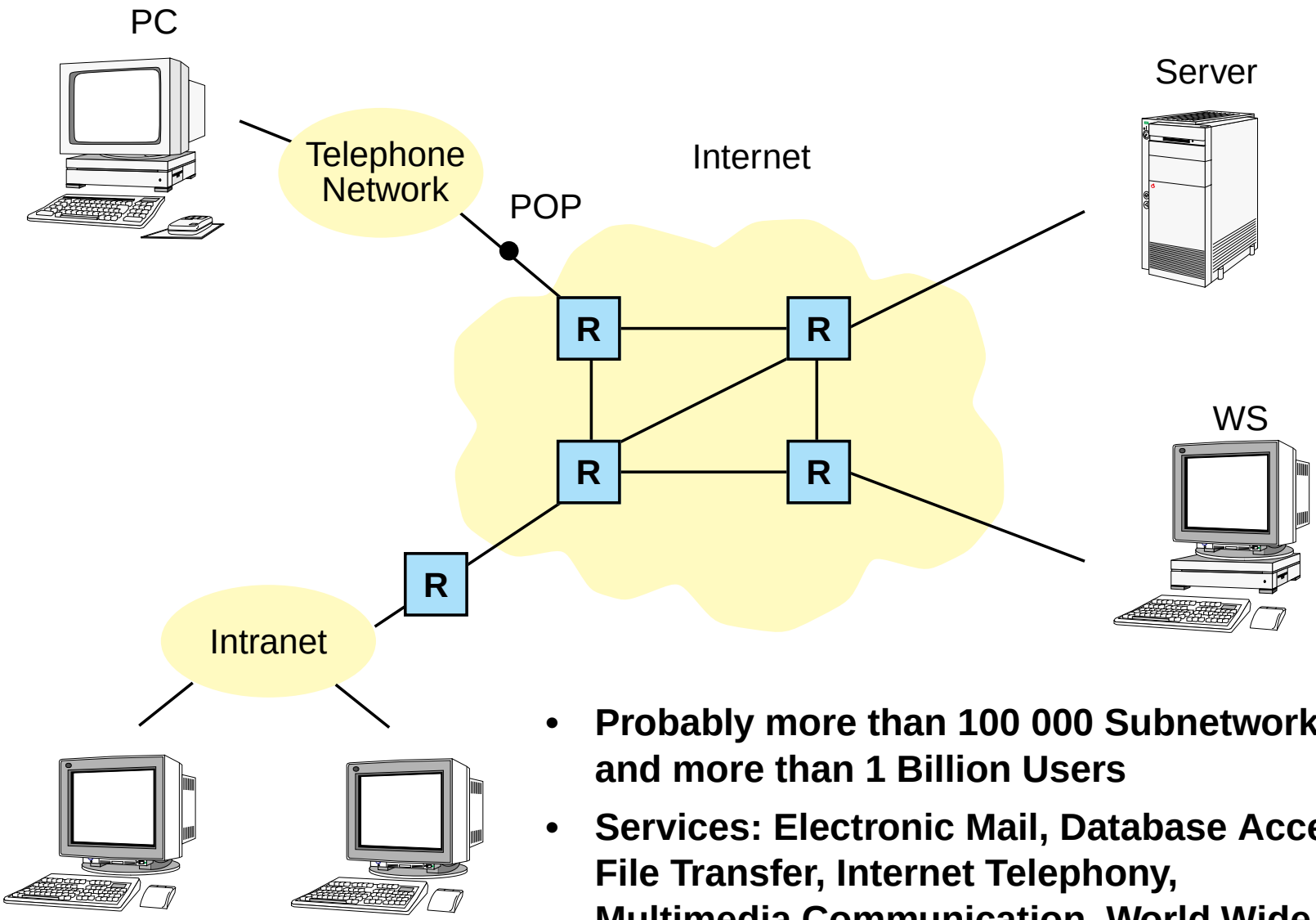
X.25 ITU Packet Standard
IPv4 Internet Protocol Version 4
IPv6 Internet Protocol Version 6
LAN Local Area Networks
MAN Metropolitan Area Networks
WLAN Wireless LAN

2.2 Telecommunication Networks



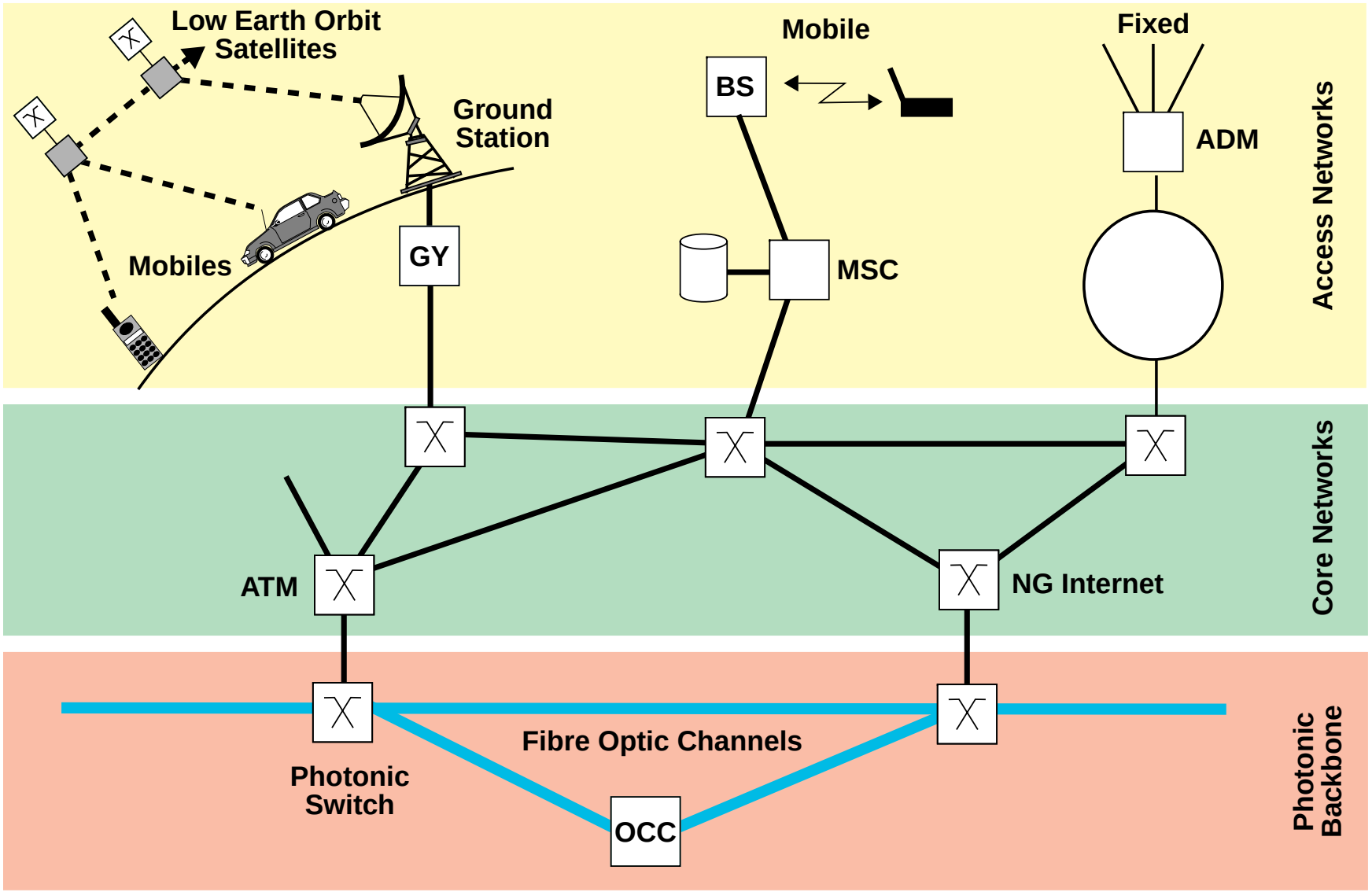
- 1500 Million Subscribers (Fixed Network)
- 3000 Million Subscribers (Mobile Networks)
- Intelligent Network Services (IN)

2.3 Computer Communication Networks

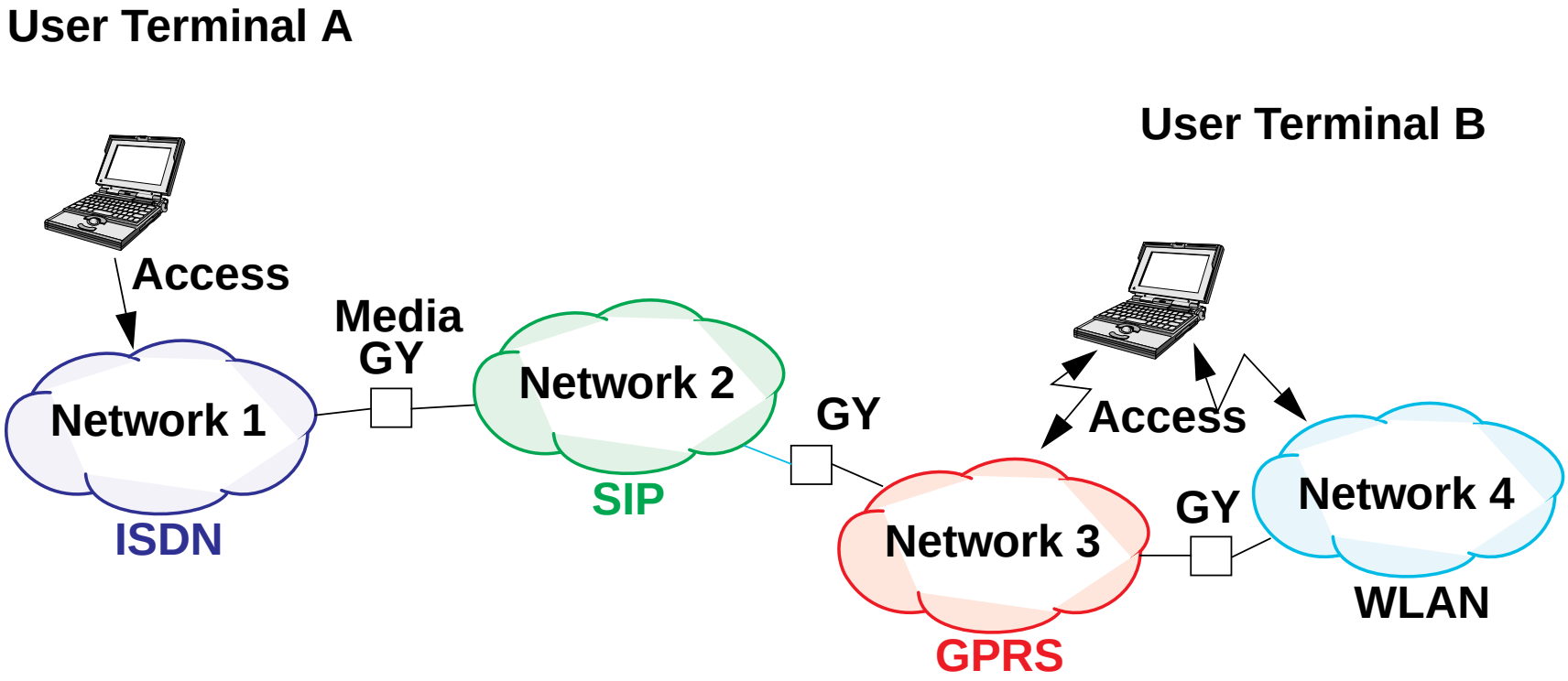


- **Probably more than 100 000 Subnetworks and more than 1 Billion Users**
- **Services: Electronic Mail, Database Access, File Transfer, Internet Telephony, Multimedia Communication, World Wide Web, Peer-to-Peer, Social Networking**

2.4 Technological Developments



2.5 Network Convergence

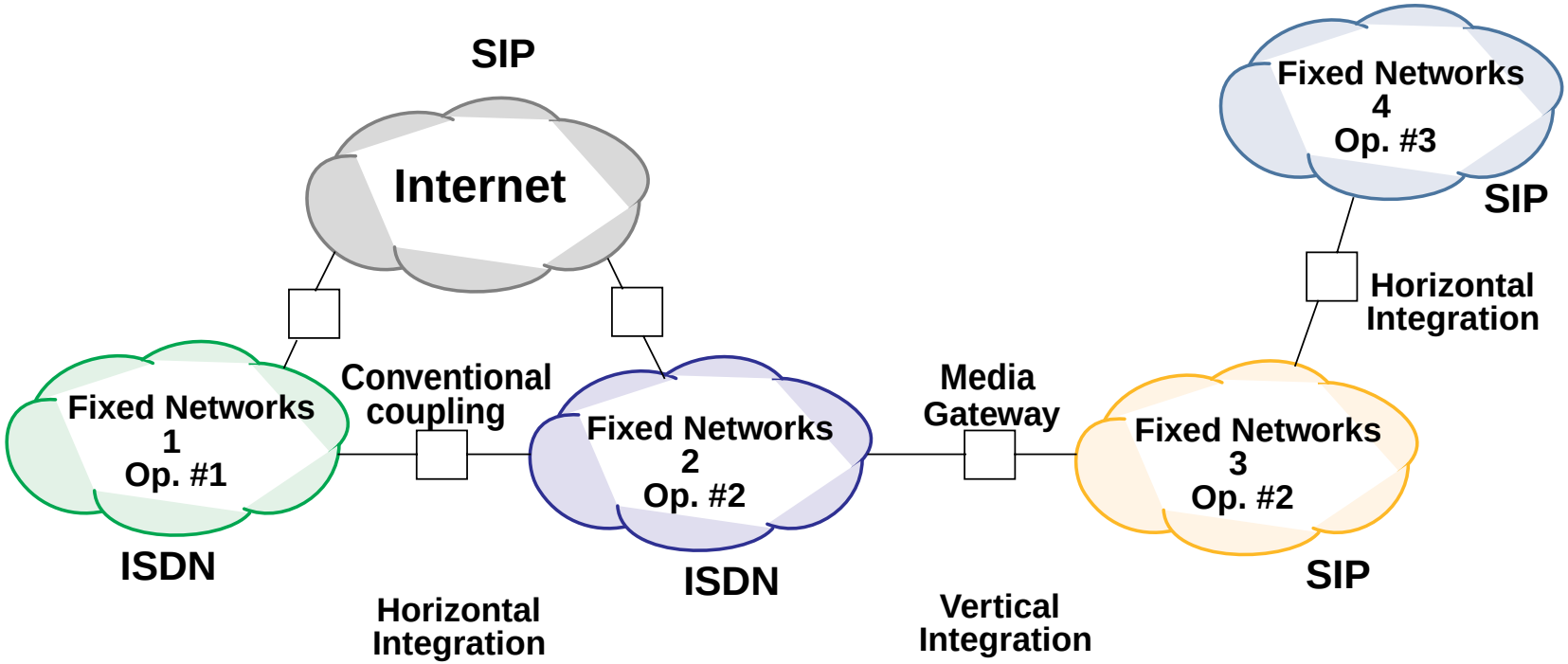


- Users may have access to networks of different technologies
- Communication across networks of identical / different technologies
- "Always best connected"
- Wide spectrum of services

2.6 Horizontal and Vertical Integration

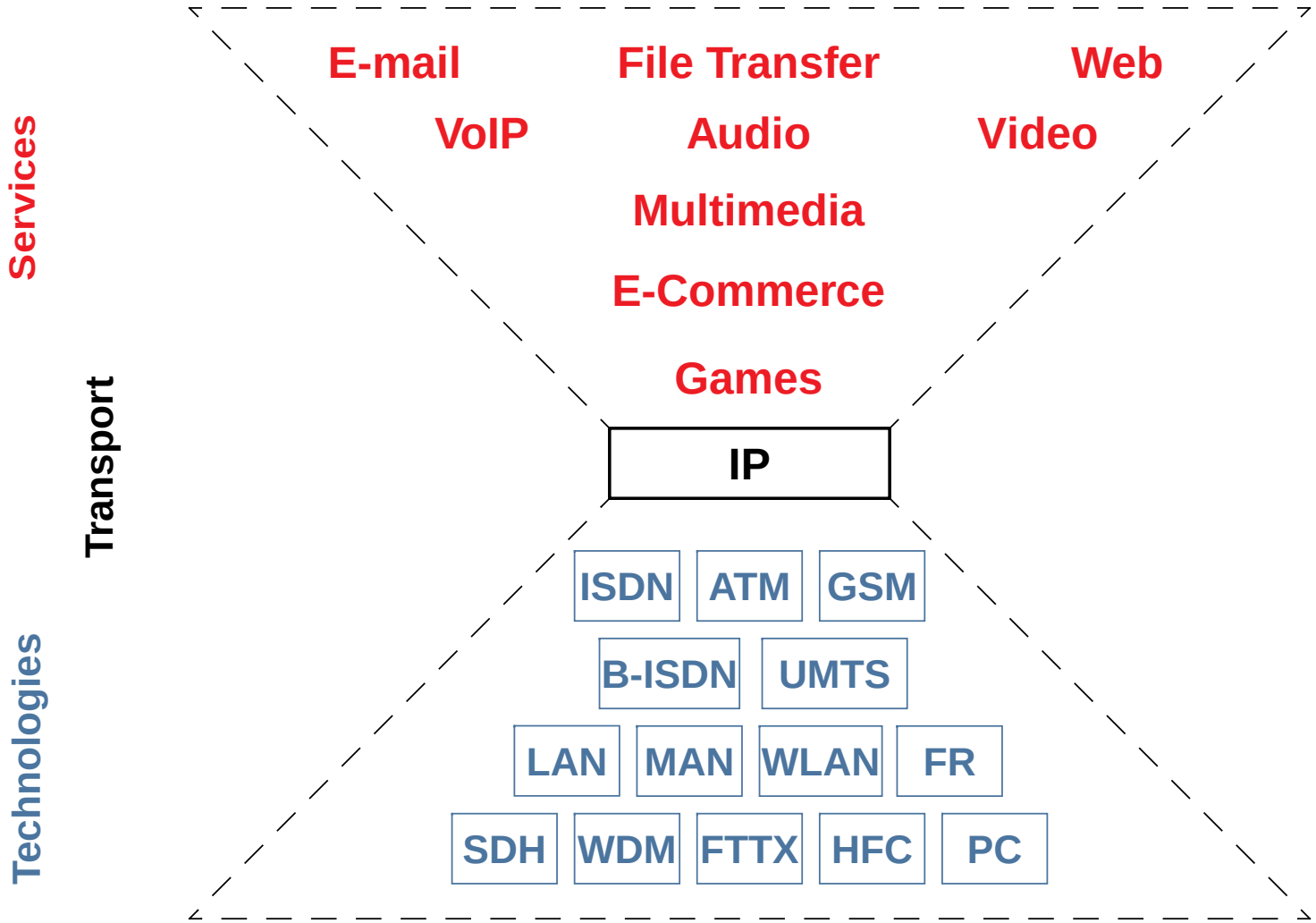
Statements: Existing networks: ISDN, Mobile Networks, Internet, ...
Future trend: IP-based networks

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



2.7 Development Scenario

Service and Technology Convergence



2.8 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")

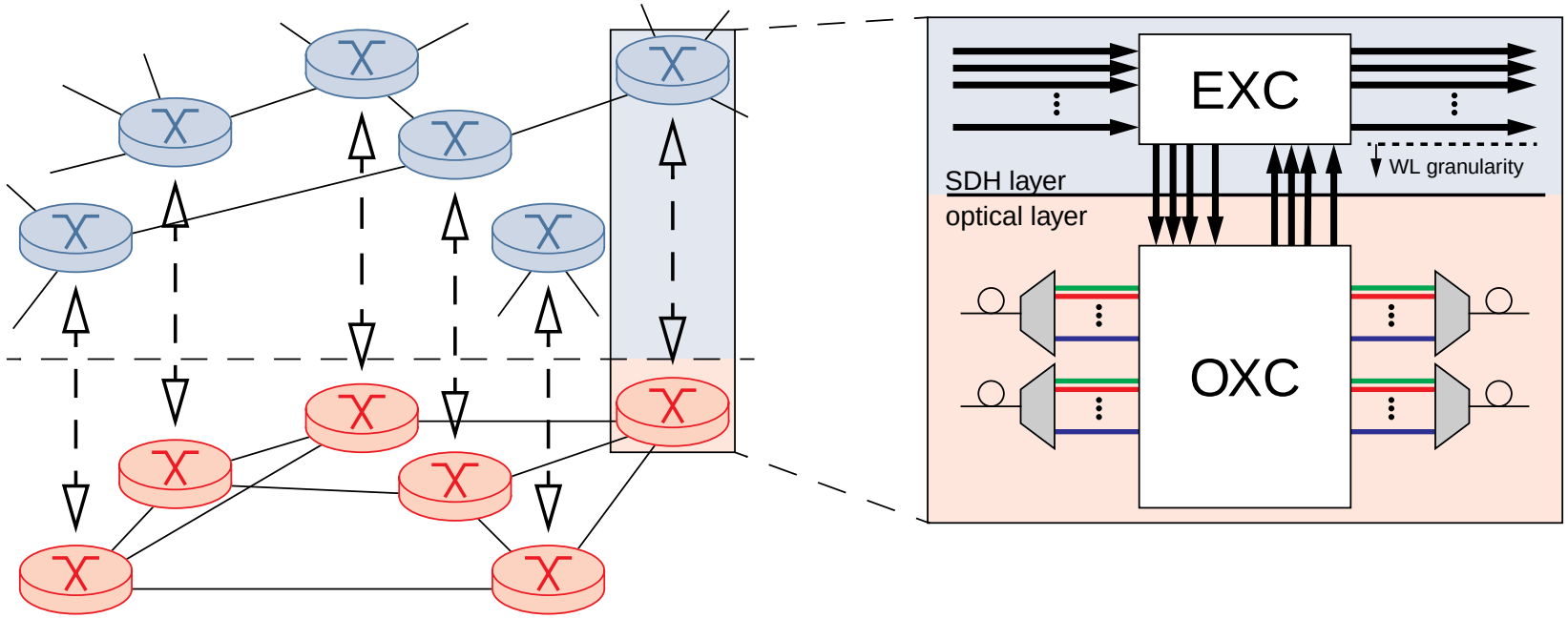
  Examples: Body (Personal) Area Networks
  Sensor / Actor Networks

Nomadic Communications

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

  Extension of the Mobile Communications Paradigm

2.9 Multilayer Network Architectures

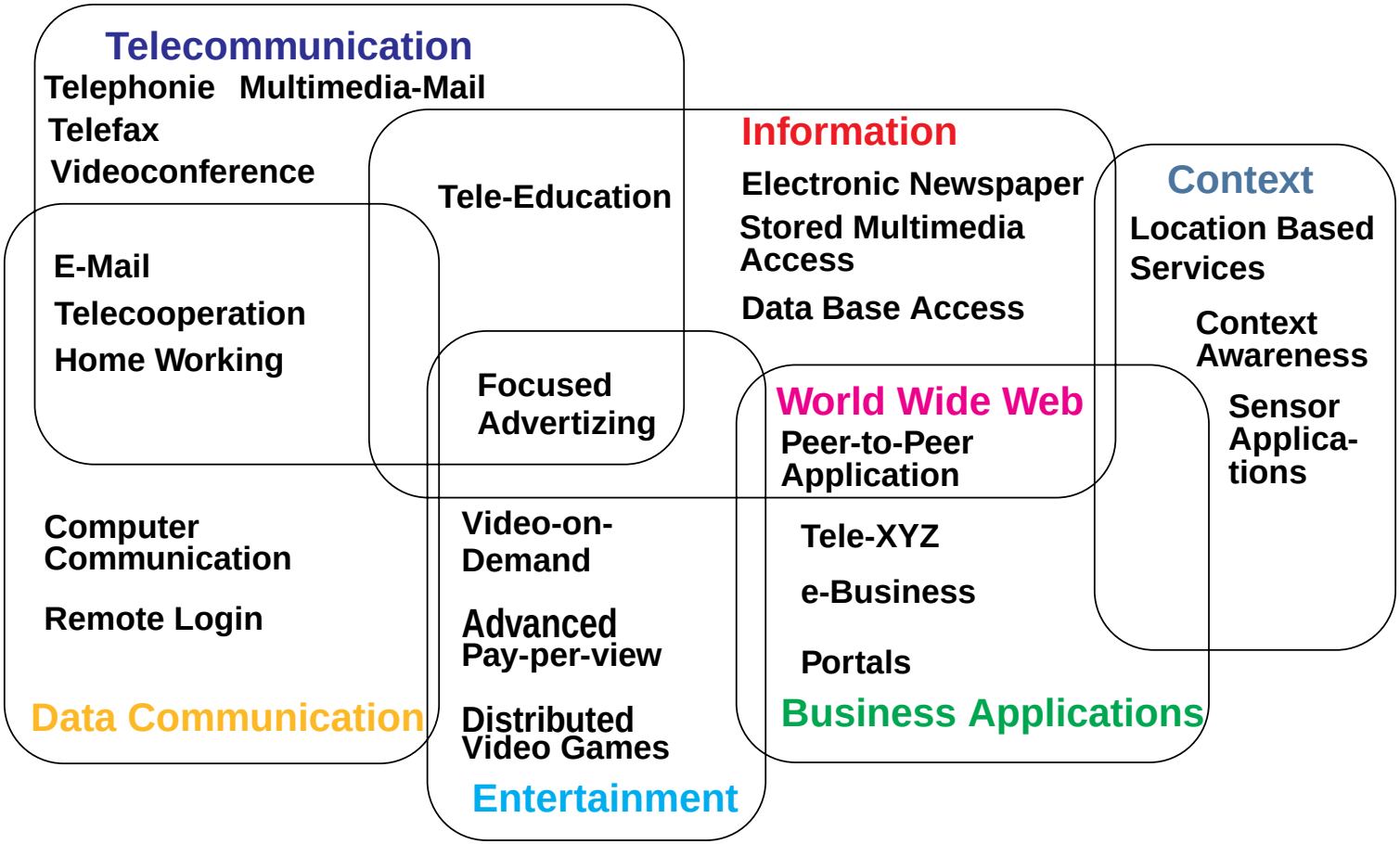


- **Circuit Switched Transport Network**
- **Evolutionary Extension of Current Core Networks**
- **Optimal combination of**
  - optical transport
  - electronic aggregation and traffic engineering

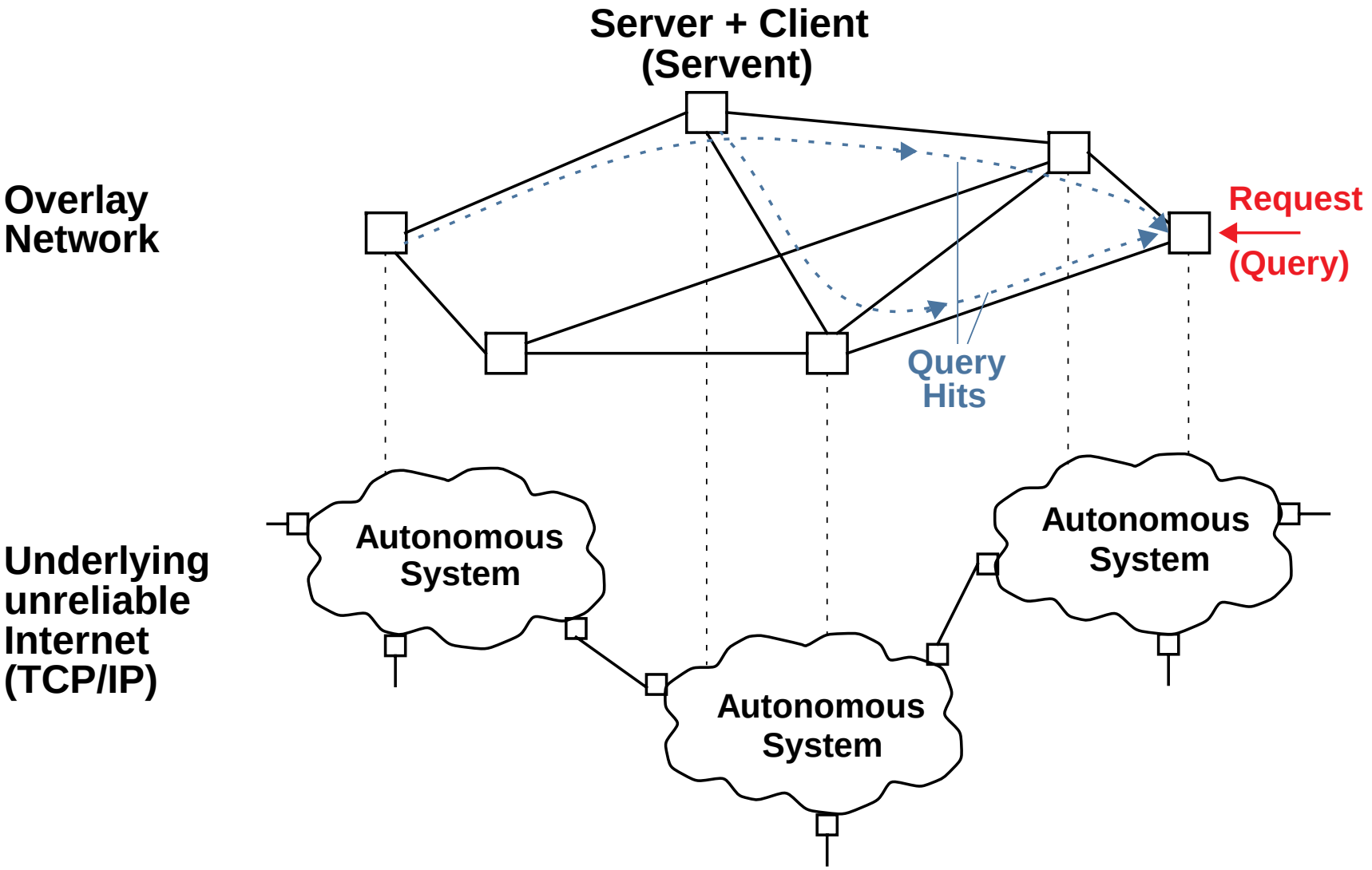
3. Development of Services and Applications

1. Application Areas and Communication Services
2. Peer-to-Peer File Sharing
3. Grid Computing
4. New Mobile Services
5. Navigation Support
6. Smart Card Applications (Example: Electronic Ticket)
7. Heterogeneous Network Access (Multi-Technology Access)
8. Location- and Context-Aware Applications

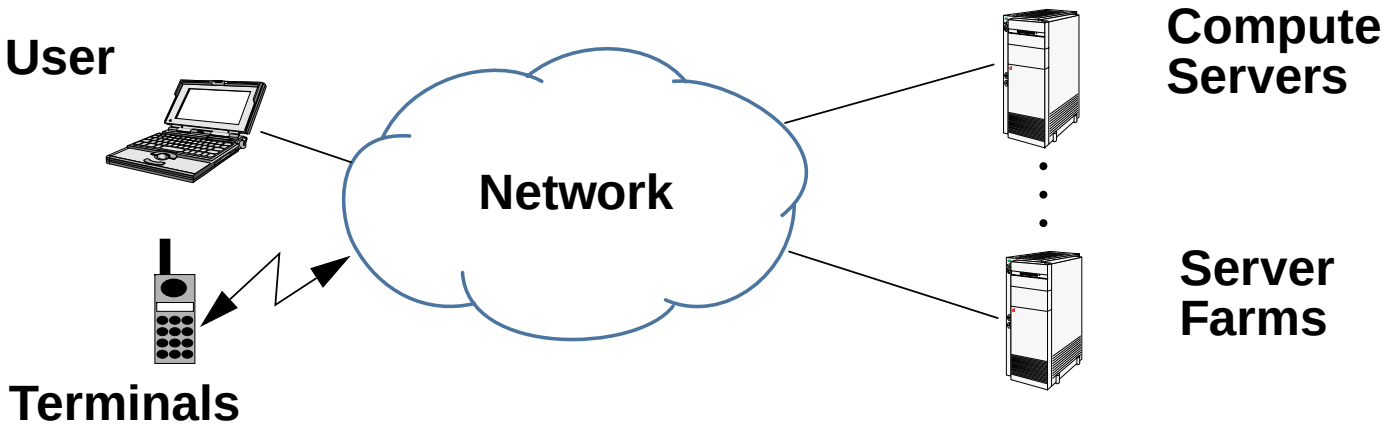
3.1 Application Areas and Communication Services



3.2 Peer-to-Peer File Sharing



3.3 Grid Computing / Cloud Computing



Charcteristic:

- Virtual Organization
- Data and Services provided by the "Grid"
- Distributed Resource Management
- Service Level Agreements
- Security (Open Grid Services Architectures)

3.4 New Mobile Services

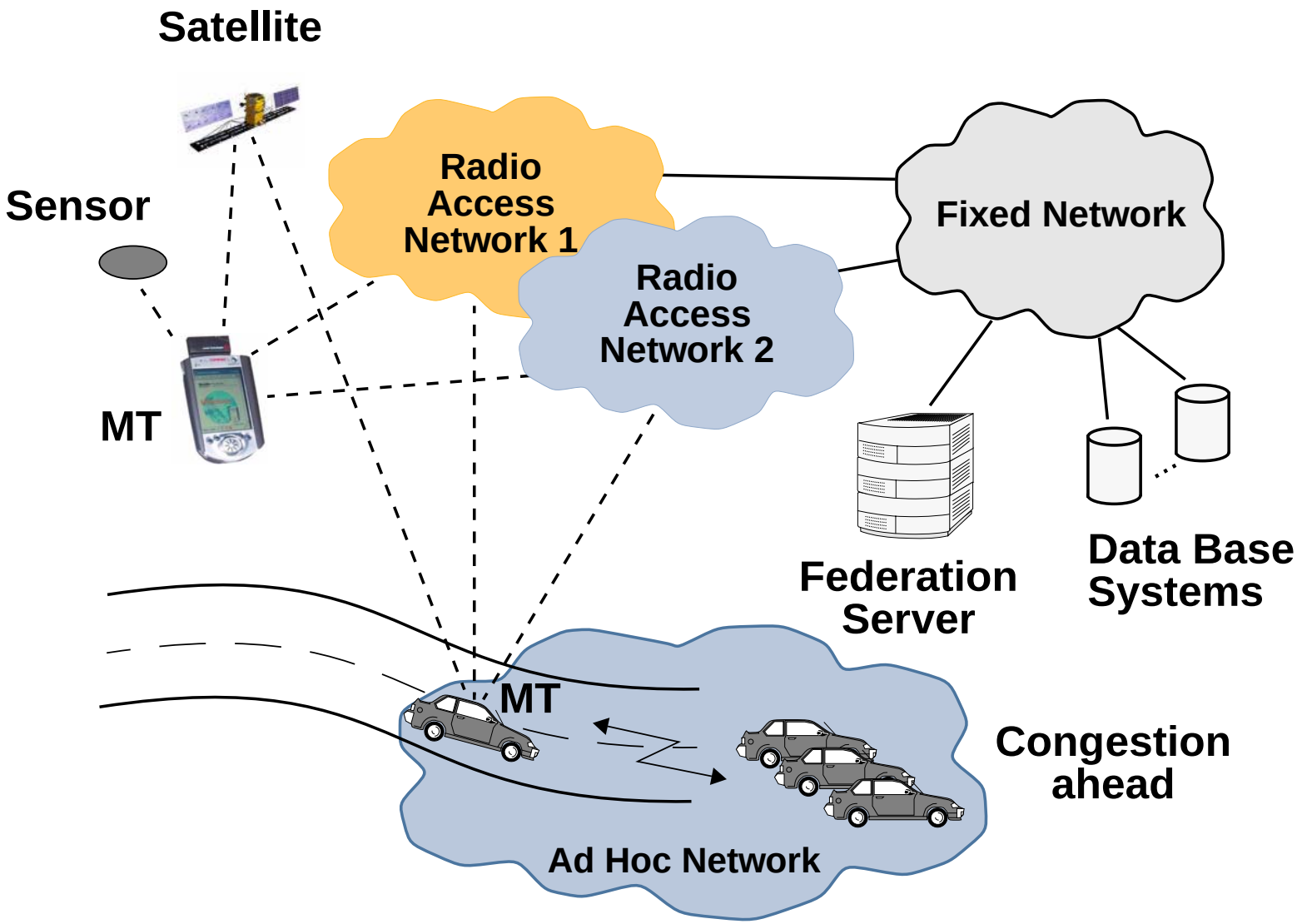
Communication Services

- **Information Services**
  - ➥ location/context aware services, navigation services, ...)
- **Classical Information Services**
  - ➥ MMS, e-mail, ...
- **Stream-Oriented Services**
  - ➥ speech and video telephony, ...

➔ Emerging Topics

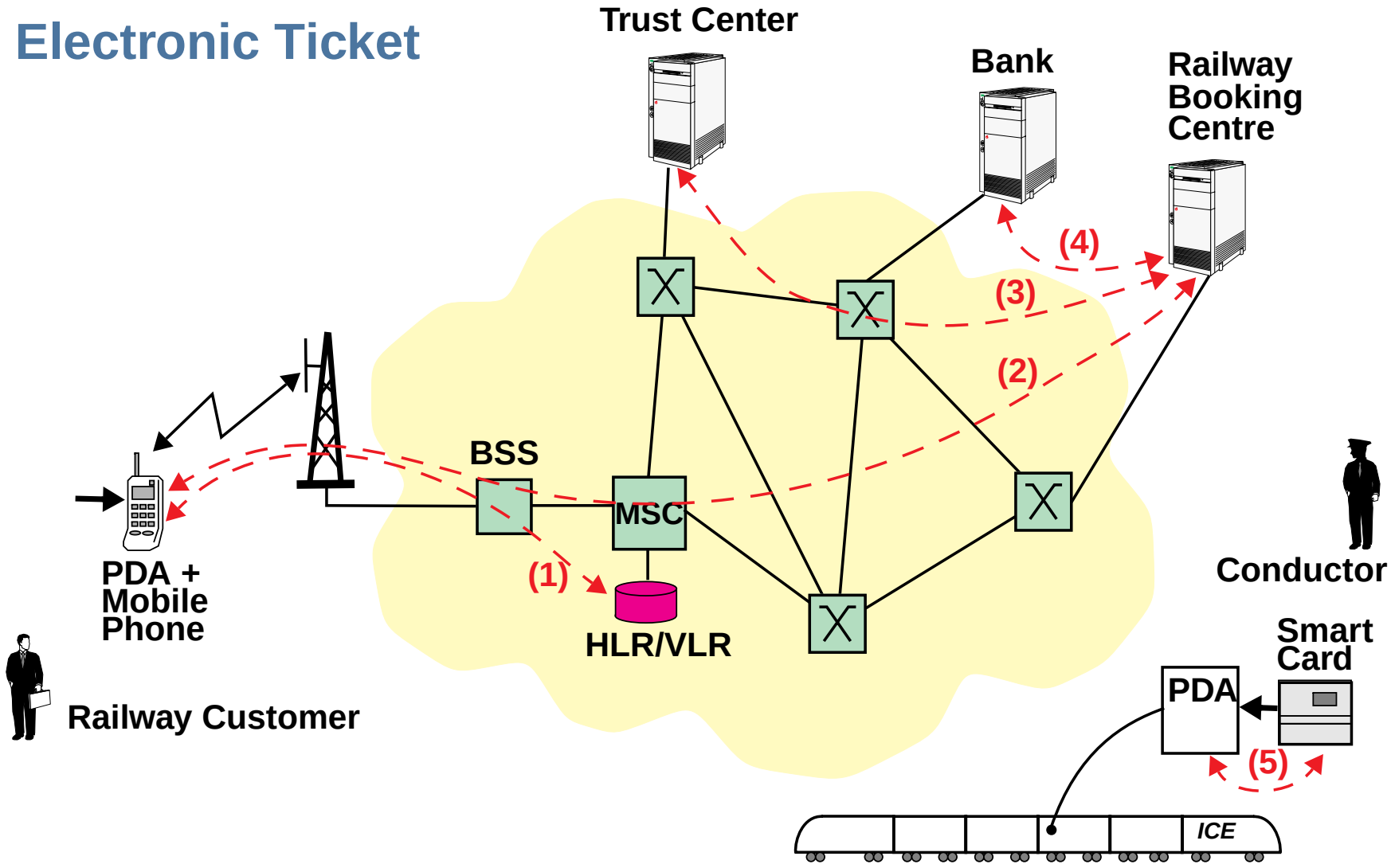
- **New Services**
  - ➥ minimalistic user interface
- **New Requirements to the Networks**
  - ➥ mobility manangement/support
  - ➥ resource reservations
  - ➥ support for hundreds of niche applications
- **Business Models**

3.5 Navigation Support



3.6 Smart Card Application

Electronic Ticket



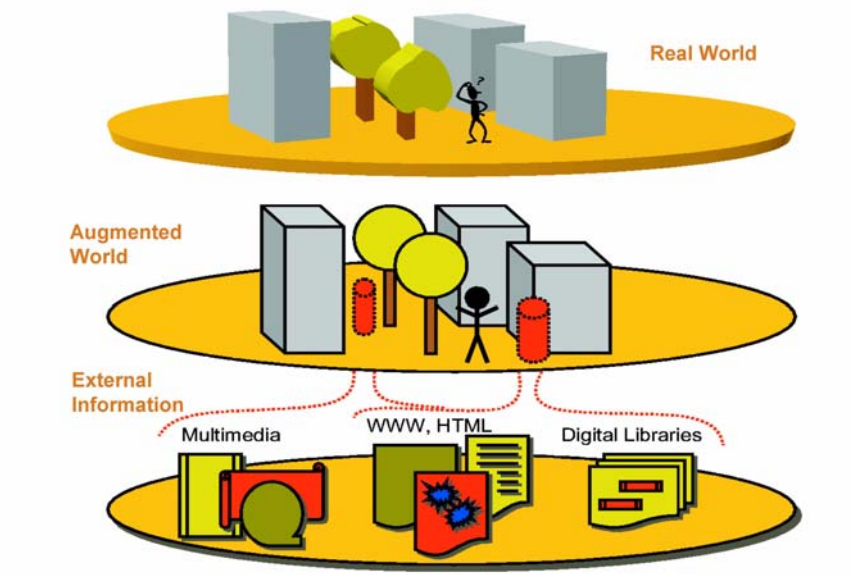
3.7 Location- and Context-Aware Applications

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**

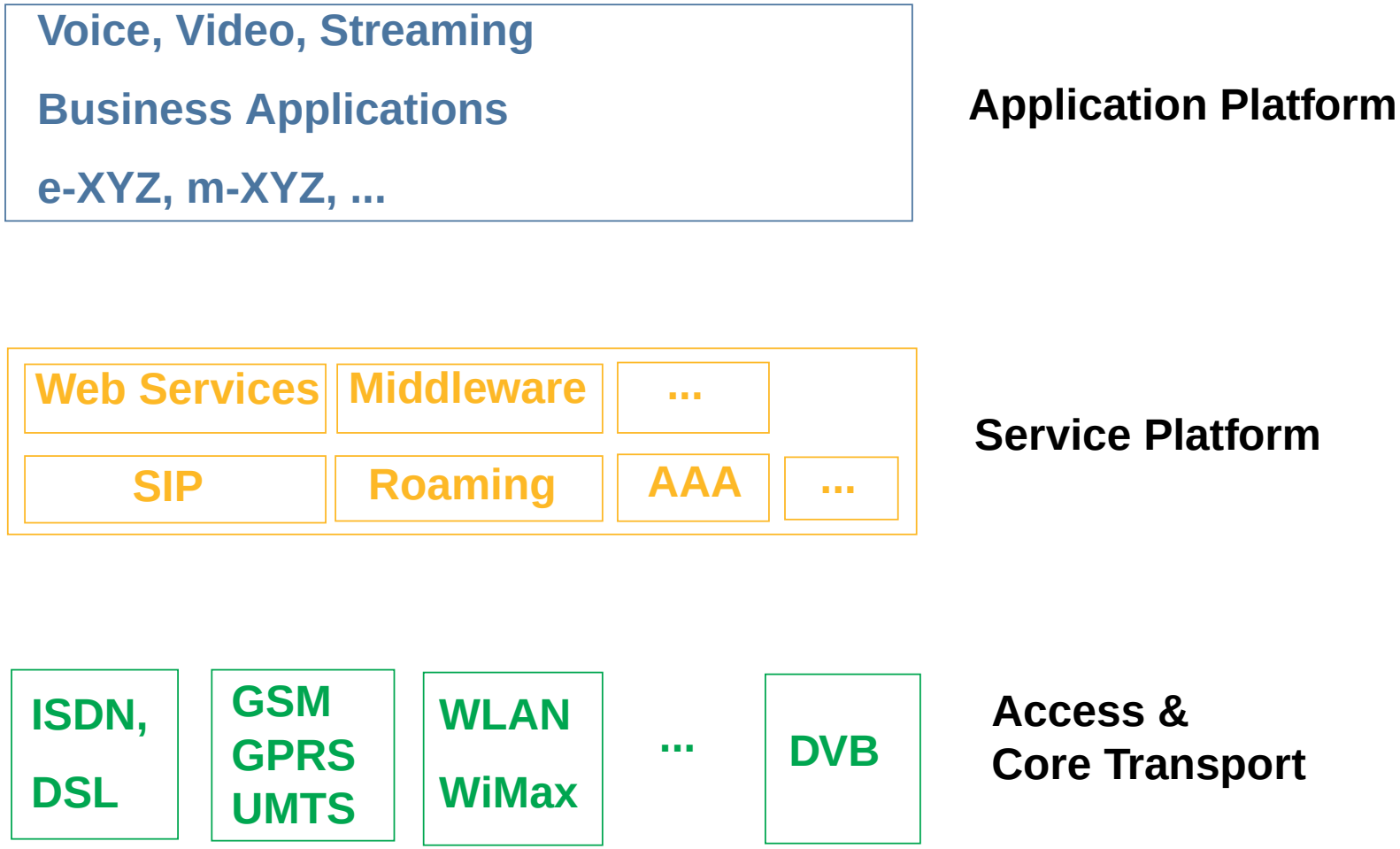
4. Problems and Challenges

1. Technical Challenges of NGN
2. NGN Service Platforms
3. QoS Management in the Internet
4. Architectures and Protocols
5. Mobility
6. Security and Privacy
7. Reliability, Resilience and Self-Organization
8. Conclusion

4.1 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 • Reliability and Self-Organization

4.2 NGN Service Platforms



Trends – Switching in Future Transport Platforms

- Traffic in the core of transport platforms is and will be highly aggregated (impacts on traffic characteristic and leads to path oriented networks)
- Applications with extrem high bandwidth demands will remain specialized

Near future network architectures: optical circuits, electronic packet switching

- Power consumption determine rack space of large-scale routers/switches
- Per packet switching not reasonable in core networks due to aggregation
- Architectures proven to scale for 10s of TBit/s but severe concern for higher rates

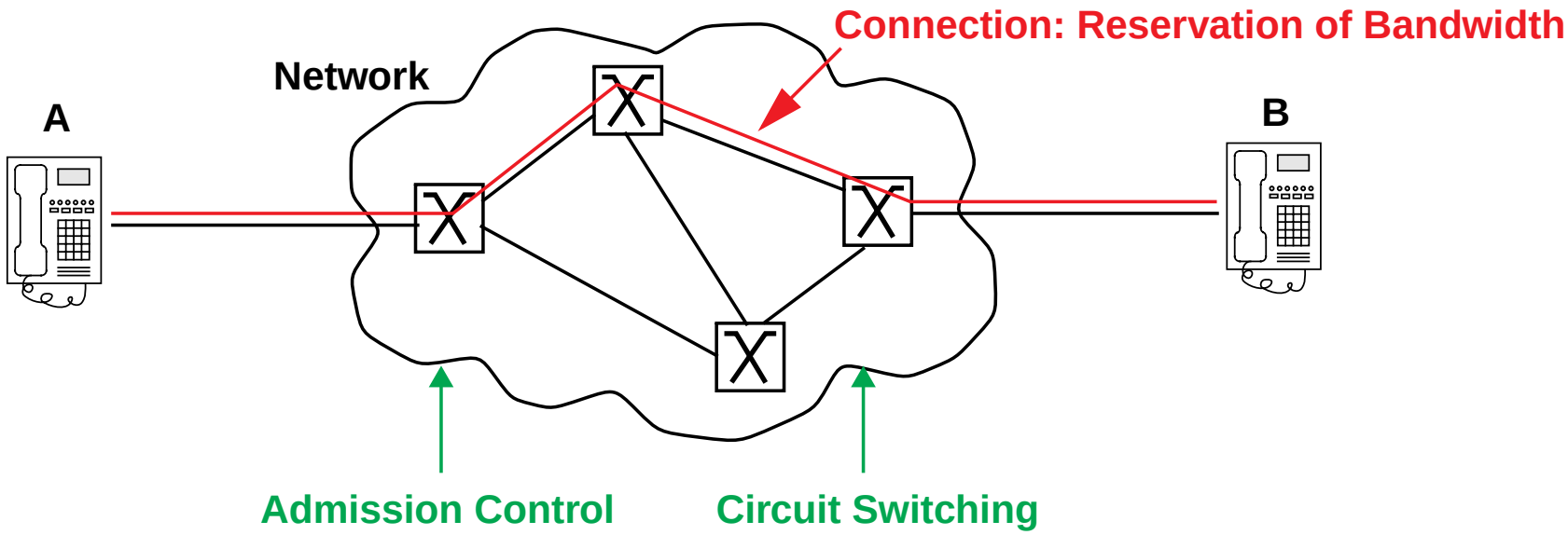
New switching paradigms

- On optical plane (O[B|P]S and hybrid architectures ORION, OpMiGua, OBTN, …)
  - Technologically today hard to implement in large scale
  - Performance gain not killer argument (especially wrt. traffic perspectives)
  - But: optical switching seems to be much less power consuming (orders of magnitude)
- On electrical layer (Flow switching, Frame switching, …)
  - Reduction of amount of data units to be handled reduces required silicon speed
  - But: edge nodes become more complex

→ Switching paradigm not clear – neither technology, nor time scale

4.3 QoS Management - Traditional Solutions (1)

Example 1: Telecommunication Services

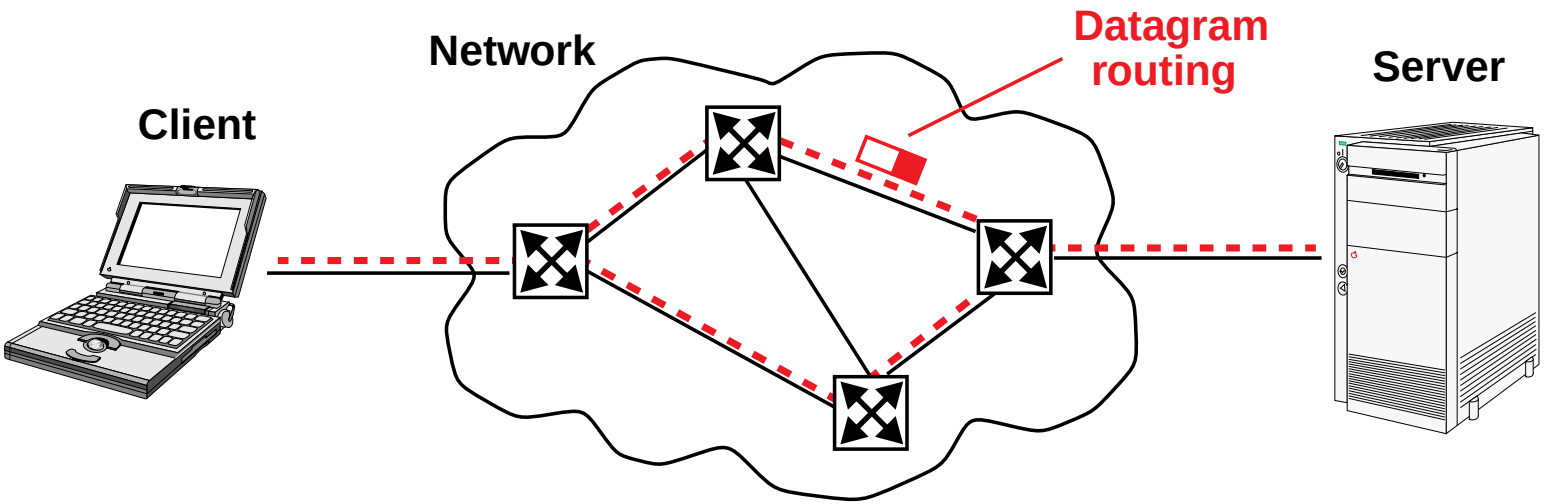


Traditional Solution is not feasible for many new applications due to:

- **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**

4.3 QoS Management - QoS in the Internet (2)

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

4.3 QoS Management - QoS in the Internet (3)

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

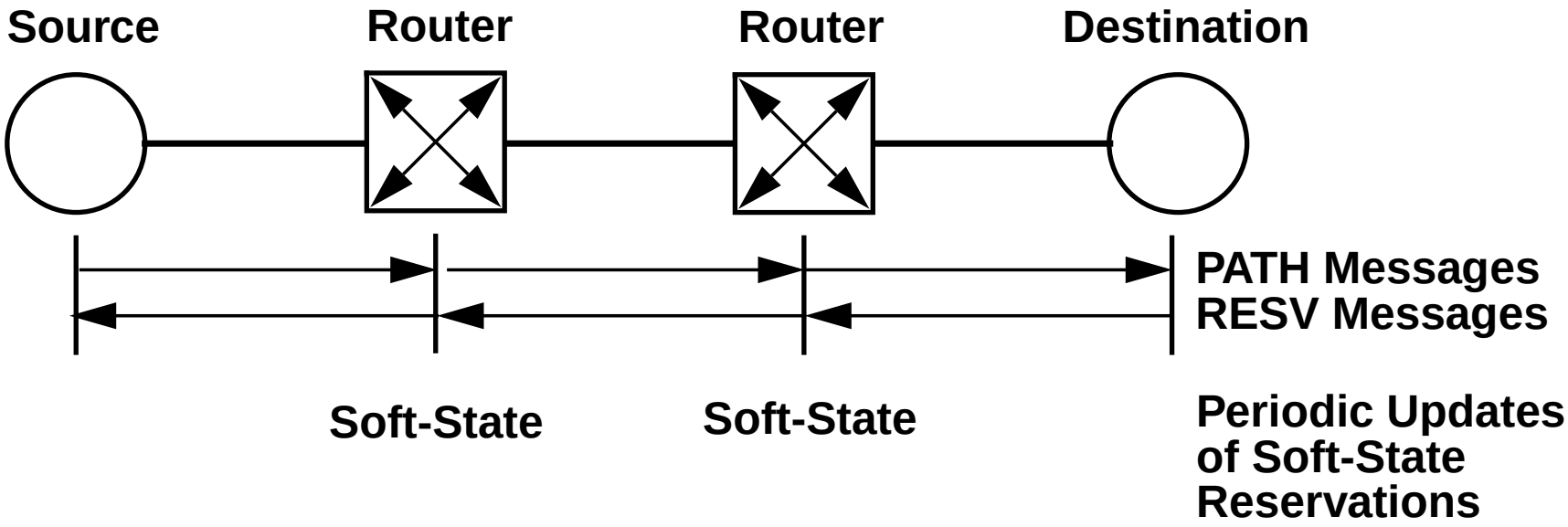
Traffic Classes in the DiffServ-Model

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

Hop-by-Hop Control

4.3 QoS Management - QoS in the Internet (4)

IntServ-Model



Flow Description by

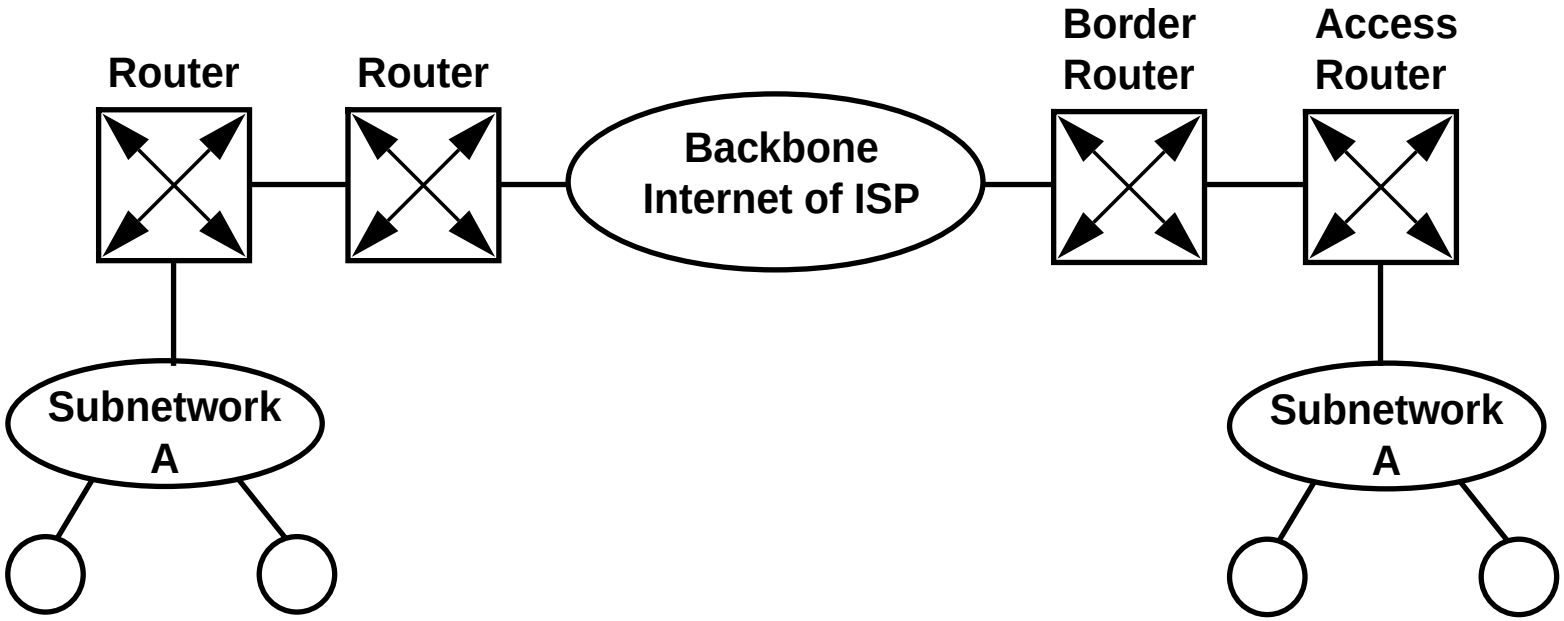
Flow Specifications (FlowSpec)

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

Filter Specification (FilterSpec)

4.3 QoS Management - QoS in the Internet (5)

DiffServ-Model



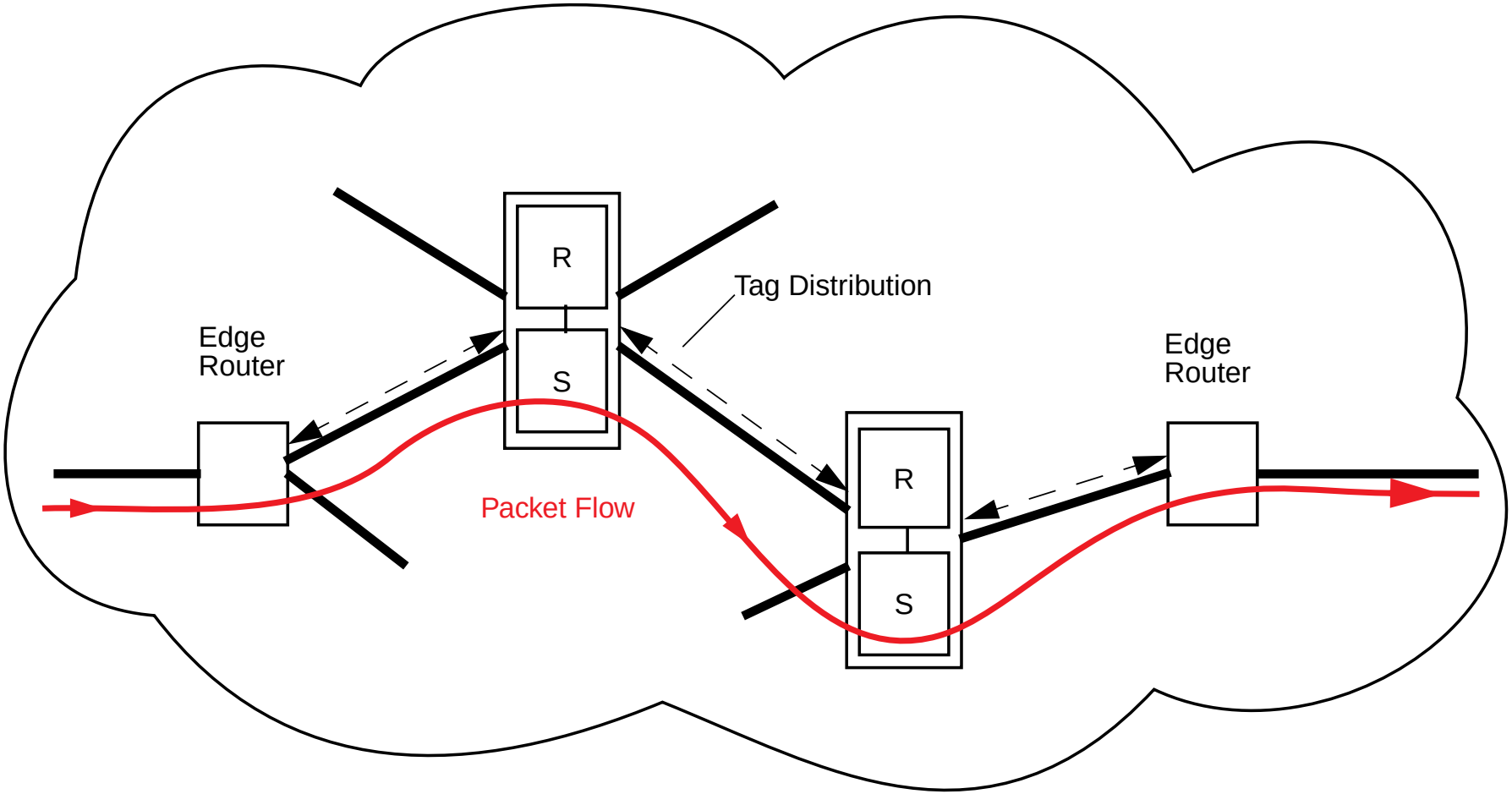
Negotiation of max. Bitrate between User and ISP for Aggregated Traffic Volumes
Classification of Traffic Class by Access Routers

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

4.3 QoS Management - QoS in the Internet (6)



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

→ **State-based switching**

4.4 Architectures and Protocols

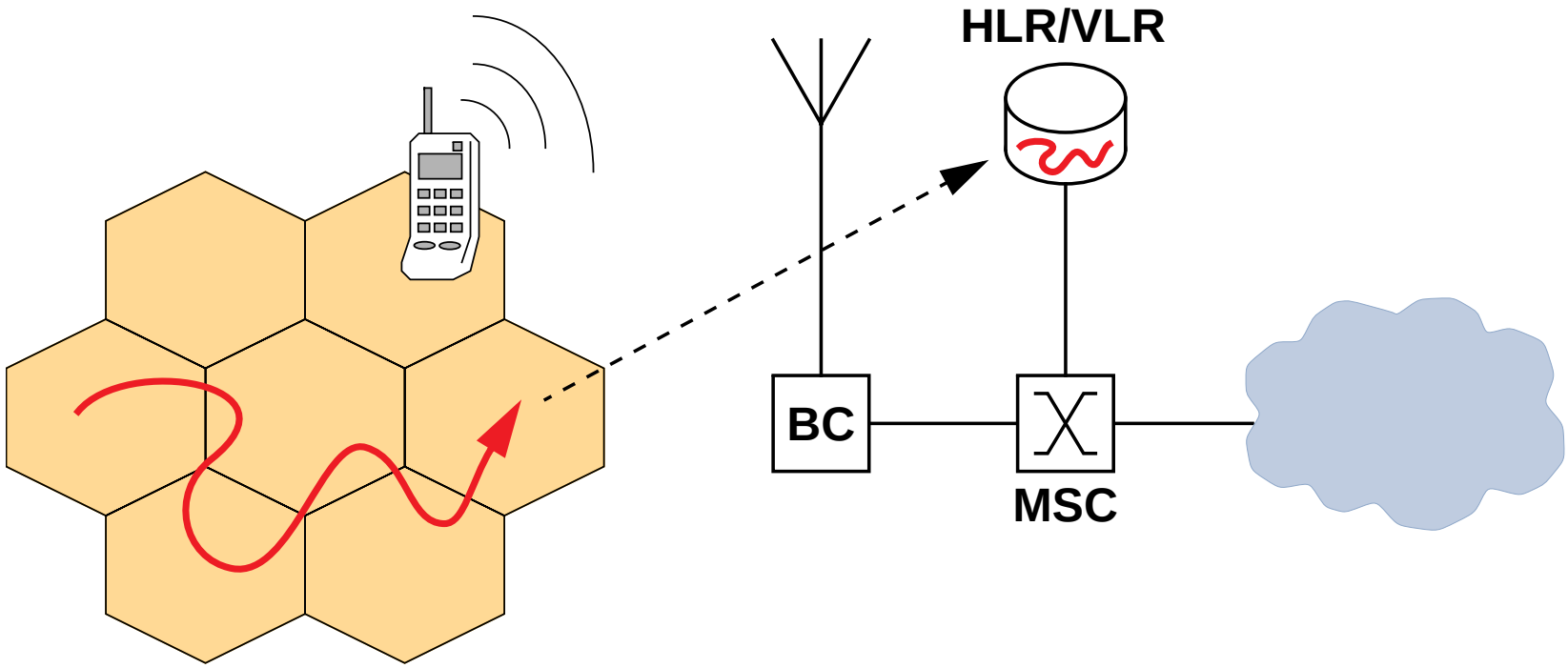
- **Unified Communication based on IPv6**
- **Communication across different Networks**
- **Mobility Management based on Mobile IP Concepts**
- **Dynamic Address Management**
- **Horizontal and Vertical Handover**
- **Integration of Ad Hoc Networks (infrastructureless)**
- **Middleware Concepts**
  Abstraction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

4.5 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**

4.6 Security and Privacy (1)

Example



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

4.6 Security and Privacy (2)

- **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**
- **Trustworthiness and Reputation Systems**

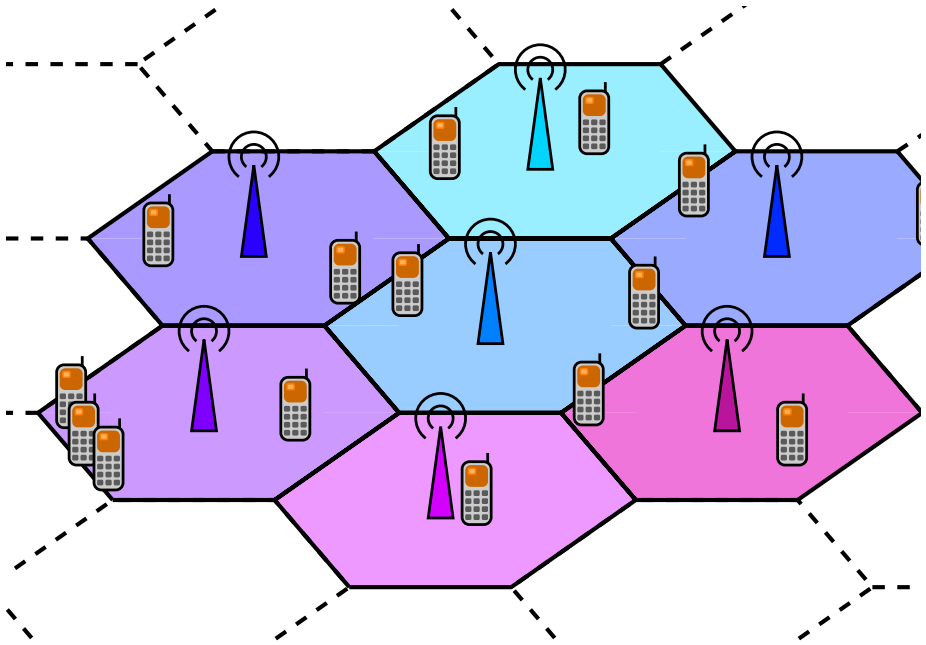
4.7 Reliability, Resilience and Self-Organization

- **Business Processes require reliable Networks**
- **Automatic Fault Detection and Reconfiguration**
- **Self-Organization**
  - Reduction of Opex
  - Plug and Play Operation
  - Adaptation to Changing Conditions
  - Manageability of Complexity

Trends – Node-Cooperation and Self-Organisation

Increased Cooperation of Network Nodes

- Focus in past was on isolated radio links
- Recent trend : Collaboration of nodes



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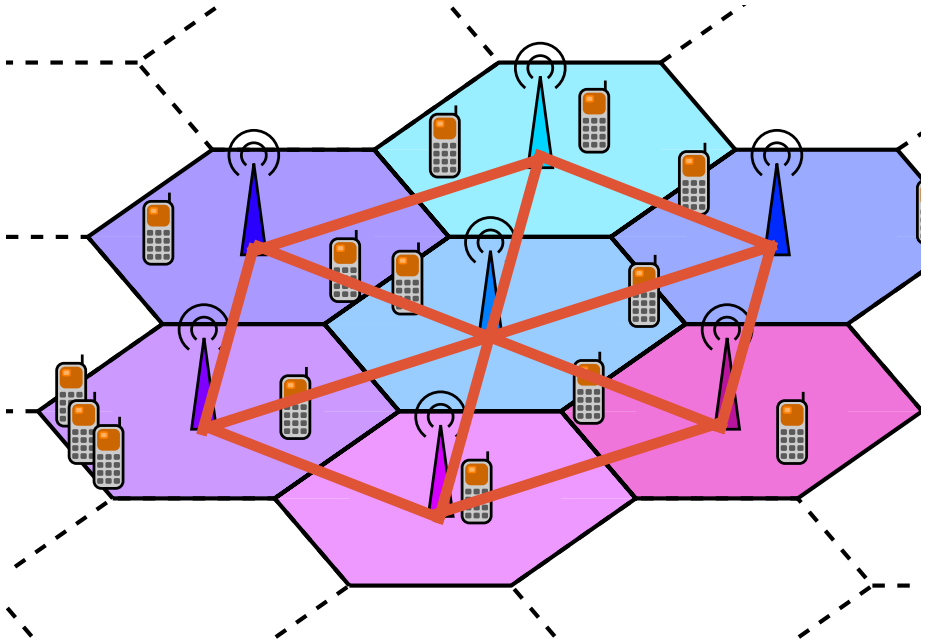

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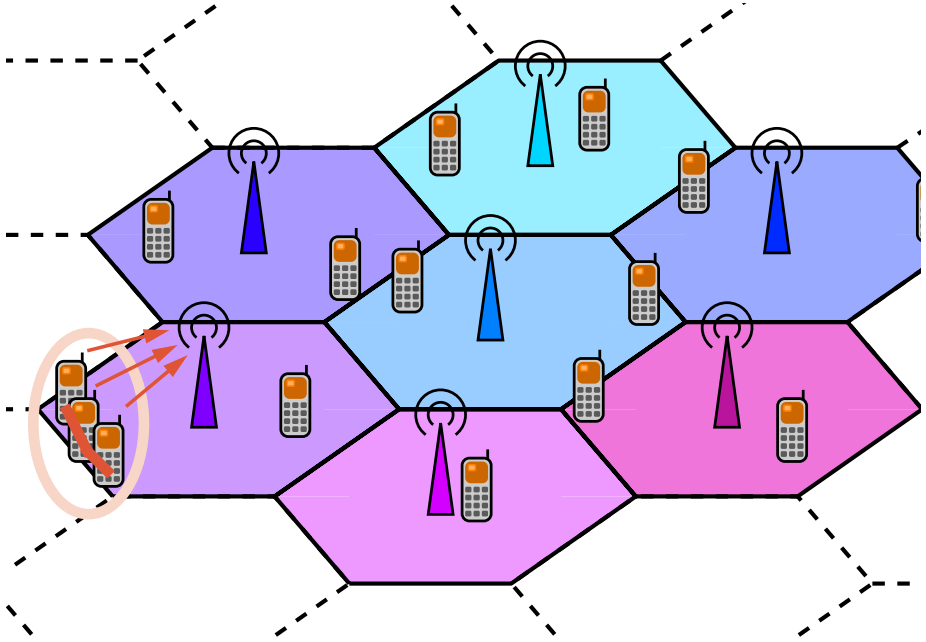
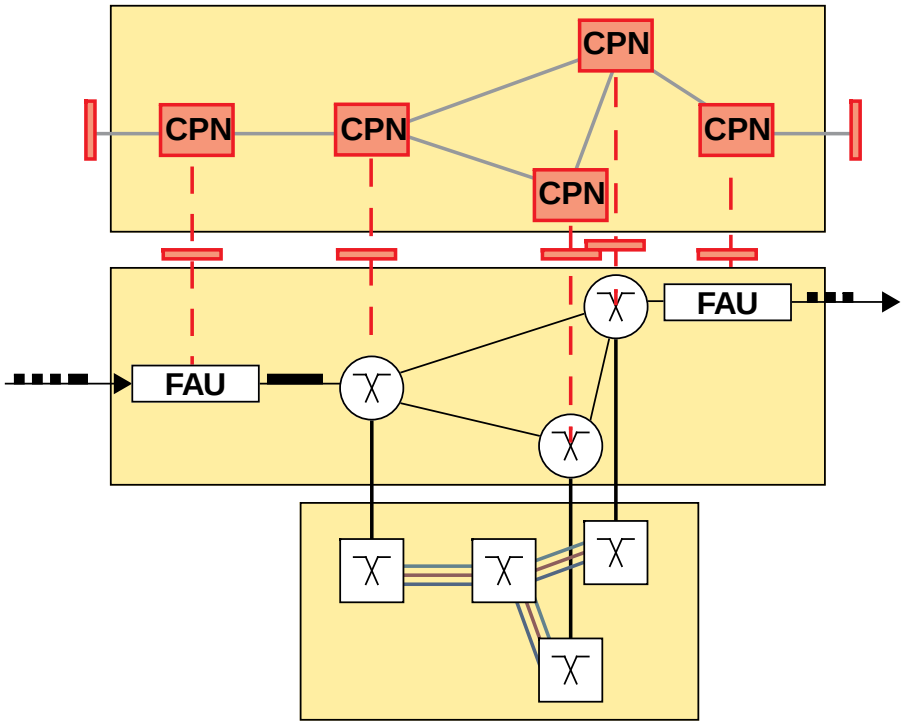
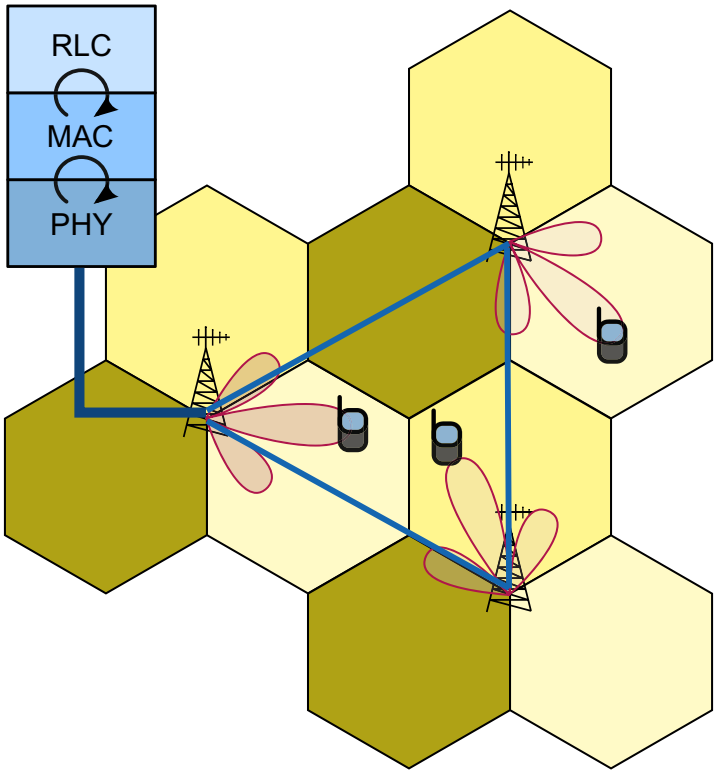
  - Collaboration of mobile terminals
    - Increased number of terminals with short range communication capabilities
    - → Dynamic multi-antenna systems (MIMO or beamforming)
  - → Potential for large performance increase



Trends – Methods for Complex Systems





- Interworking of technologies, layers, planes, relevant timescales, …
- Cross-layer integration, inter-site coordination & physical effects

- Increasing system complexity challenges current evaluation methodology
- Understanding of all aspects and integrated evaluation is almost impossible

→ Need for new methods

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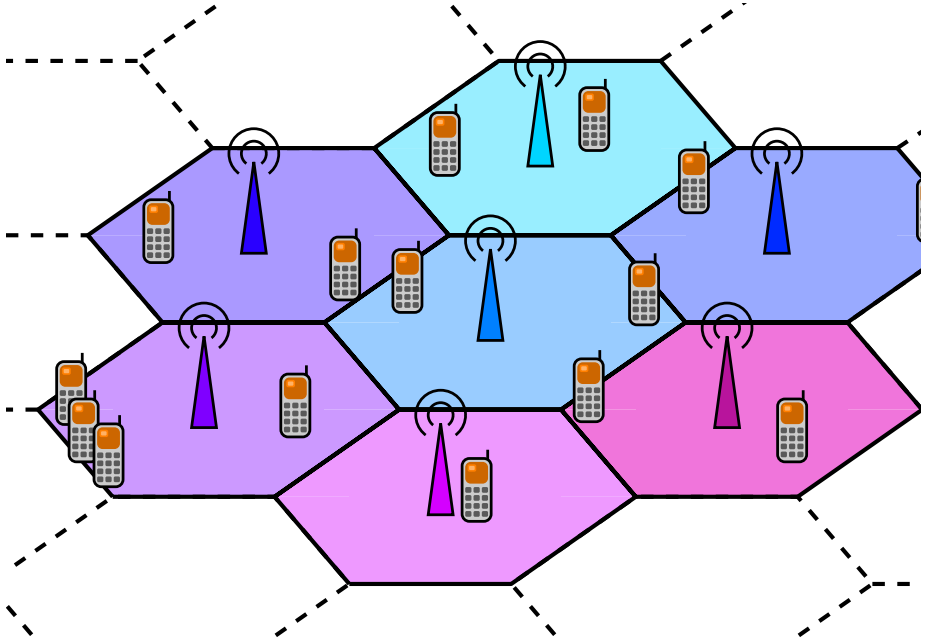


Self-Organizing Networks

- Increasing complexity of networks: number of parameters, algorithms & technologies
- Increasing dynamicity of networks: node collaboration, variable cell capacities

→ Approach: higher degree of automation in wireless networks

- → Self-Configuration capabilities to decrease cost and simplify network management
- → Self-Optimization capabilities as the key to efficient network operation & performance gains

Examples of SON use cases

Next Generation Mobile Networks (NGMN) Alliance

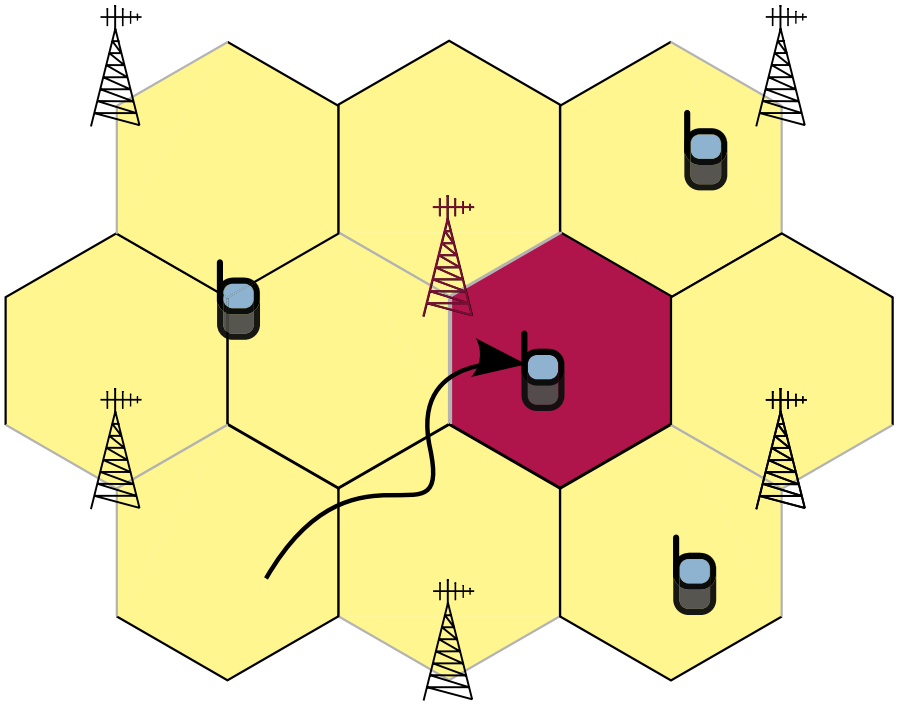
- "Plug'n'Play" Basestations
  - Configuration of BS is determined in planning process using system measurement data
  - Automatic downloading of radio and transport network parameters from OMC
  - Software updates: version management and atomic update procedures
- Performance management & reporting in real-time

  For debugging purposes and monitoring of key-performance-indicators
- Radio Parameter optimization
  - Optimization of neighbor cell list and handover thresholds
  - Interference Control
- Cell outage detection & compensation

Base Station Outage Detection

Base Station (BS) Outages

- Negative impact on network performance & user satisfaction
- Difficult & costly to find



Goal

- Automated, algorithmic detection of outages and failure causes
- Self-healing capability, i.e. autonomous (temporary) compensation of the failure

Examples of possible BS failures

- Hardware failures: HF components, CPU, memory, plugs, cabling...
- Software failures: Bugs, memory-leaks, deadlocks, version conflicts...
- External influence: Power outage, transport network failures, environmental changes
- Misconfiguration: Suboptimal/wrong parameter settings

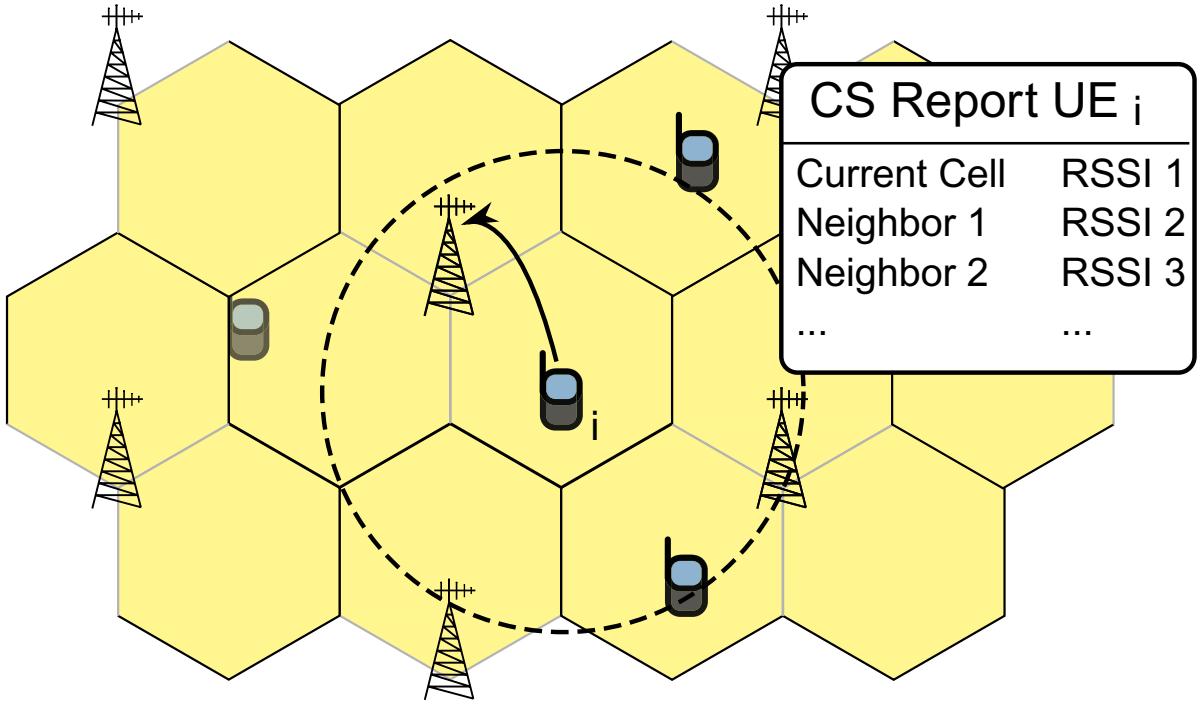
→ Huge number of different kinds of failures and failure indications

Candidate Set-based Outage Detection

Here: Quickly detect failures of HF components that render a cell invisible

Candidate Set (CS) Reports

- Mobiles (UEs) continuously scan for neighbor cells
- For potential handovers, active UEs report to the network
- Regular reporting intervals in GSM and UMTS

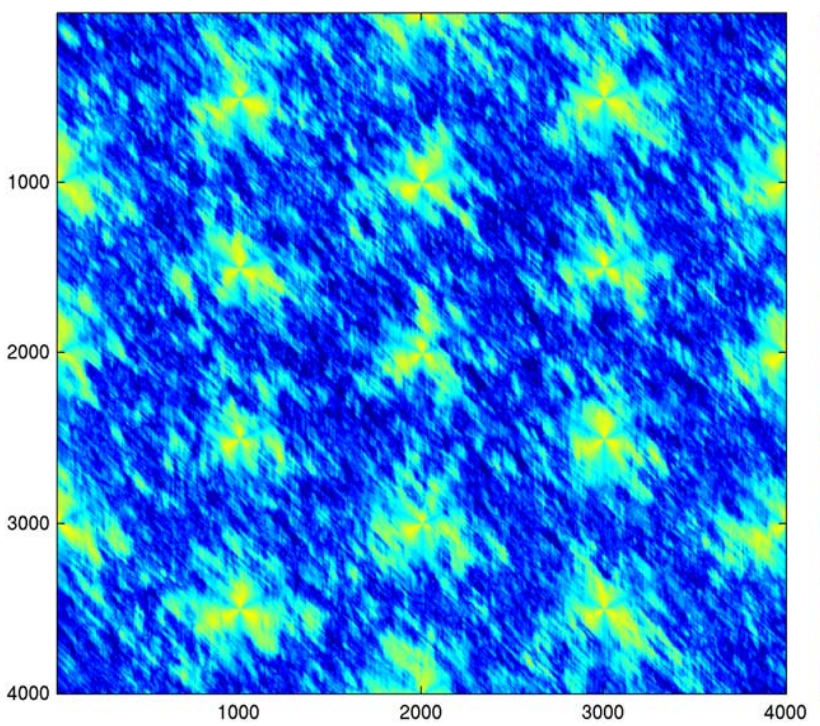


Main Idea

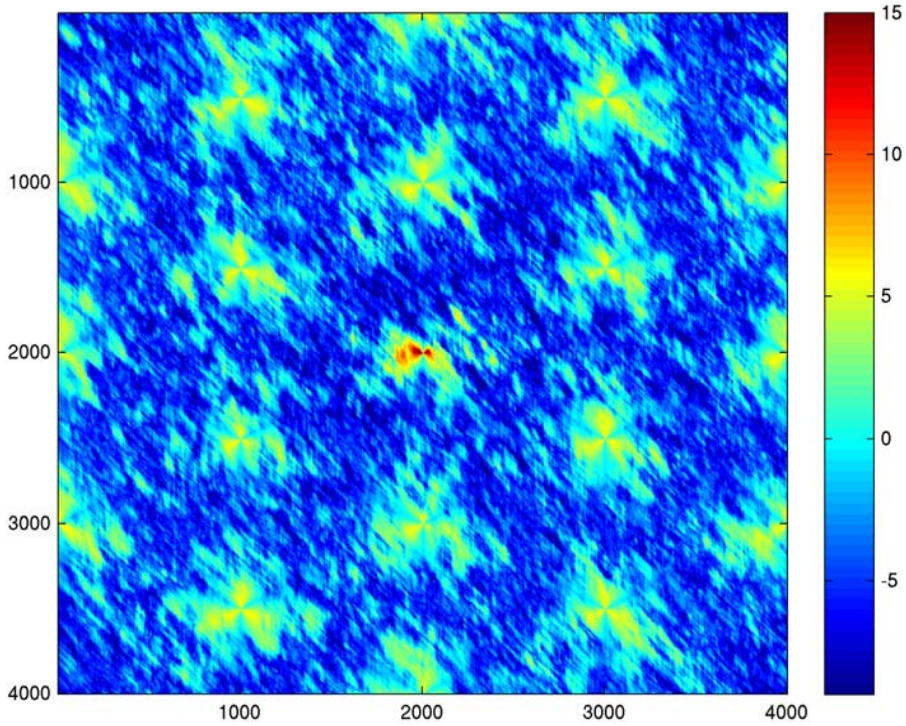
- Collect measurement data from mobile terminals
- Combine data with current cell load status
- Construct graph of visibility relations
- Monitor changes in this graph
- In the sequence of graph patterns, detect anomalies

Cell Outage

SINR plots with shadowing (Re-Use 1, high load)



No Outage



Outage

57 cell scenario, location-dependent shadowing

4.8 Conclusions: General Observations (1)

- **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

4.8 Conclusions: Research Areas (2)

- **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