Freie Universität Berlin

Telematics

Chapter 4

Opening the Internet Blackbox: Terminology, Concepts

Dr. habil. Emmanuel Baccelli

INRIA / Freie Universität Berlin

Institute of Computer Science

Computer Systems and Telematics (CST)

CONTENT of this CHAPTER

- Types of Networks
- Why layers, protocols and services?
- Types of Services
- Alternative layer models (OSI)
- Standardization

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Classification of Networks

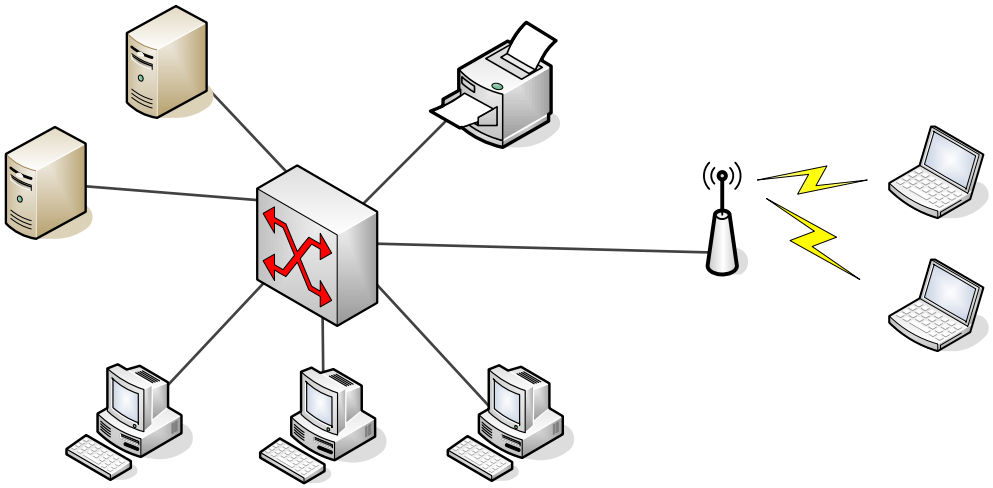
Classification of networks by **distance:**

Scope	Example	
1 m	Body	Body/Personal Area Network (BAN, PAN)
10 m	Room	Local Area Network (LAN)
100 m	Building	
1 km	Campus	Metropolitan Area Network (MAN)
10 km	Town	
100 km	Country	Wide Area Network (WAN)
1000 km	Continent	
10000 km	Planet	Internet

Local Area Networks

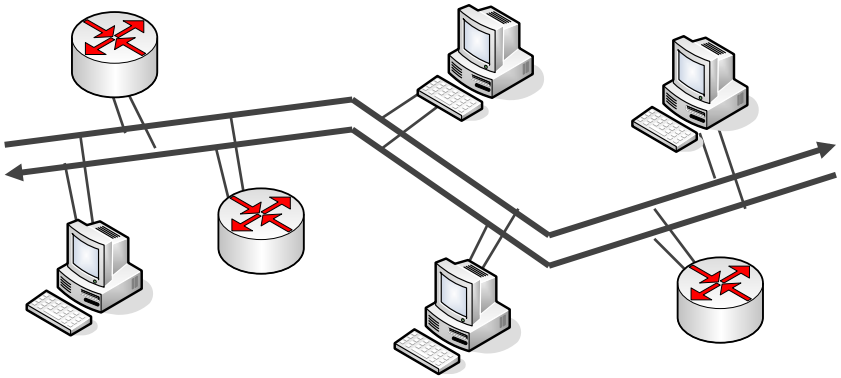
- Local Area Network (LAN)
  - Communication infrastructure for a restricted geographical area (10 m up to some km)
  - Usually maintained by a single organization
  - Used to link PCs for exchanging information & sharing peripherals and resources
  - Transmission capacity up to 1Gbps or 10Gbps
  - Transmission delay of a message in the range of milliseconds (~10 ms)

- Basic LAN topologies
  - **Star**
  - Bus
  - Ring
  - Tree
  - Meshed network



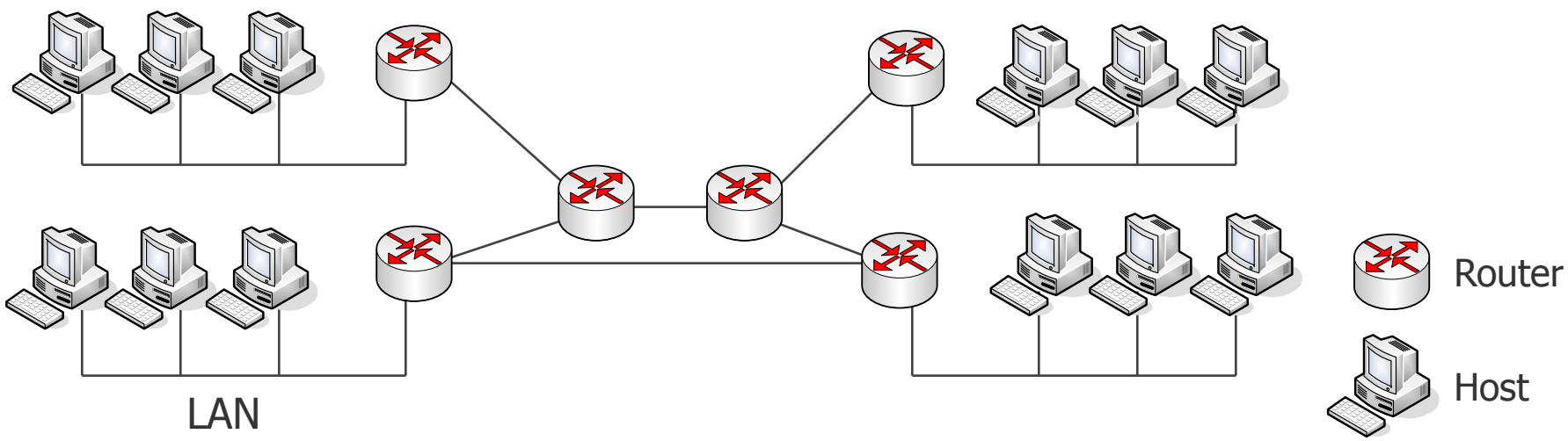
Metropolitan Area Network (MAN)

- Designed for larger distances than a LAN
  - e.g. the goal is to span across a city
  - Managed by a single entity (in general)
- No dominant topologies, essentially deployment-specific
- Generally it's 1 or 2 long cables using similar technologies as in a LAN
  - Main difference to LANs: use of time slotted communication



Wide Area Network (WAN)

- Goal of WANS it to connect LANs and MANs over **large distances**
  - Bridging from inter-city distances to intercontinental distances
- Consists in routers connected to one another through point-to-point links
- Complex topologies, deployment-specific
  - interconnection of subnetworks, owned by multiple independent organizations



Important Terms

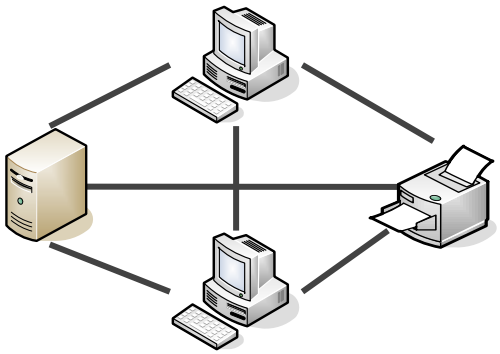
- Switch
  - A switch is a multi-connector hub for computer's cable connection to the local network. The switch maintains knowledge of exactly which computer is currently plugged in at which connector (address of the network interface card) and, based on this knowledge, forwards data to destinations in the local network.

- Router
  - A router is a computer that acquires and maintains knowledge about paths to remote destinations, that are outside of the local network, only reachable through several intermediate computers or switches. Typically, routers deal with global (IP) address information and, based on their knowledge of the global topology, forward data through several intermediate computers or switches.

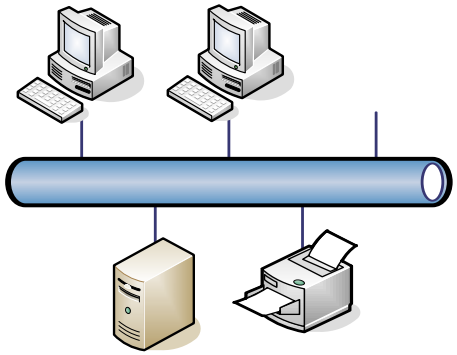
- Backbone
  - A backbone is a *connex* set of computers (usually routers) which are connected by point-to-point links. Typically, a backbone is used to cover a large region with a communication network, by interconnecting a series of smaller local networks.

Classification of Networks by Communication Technique

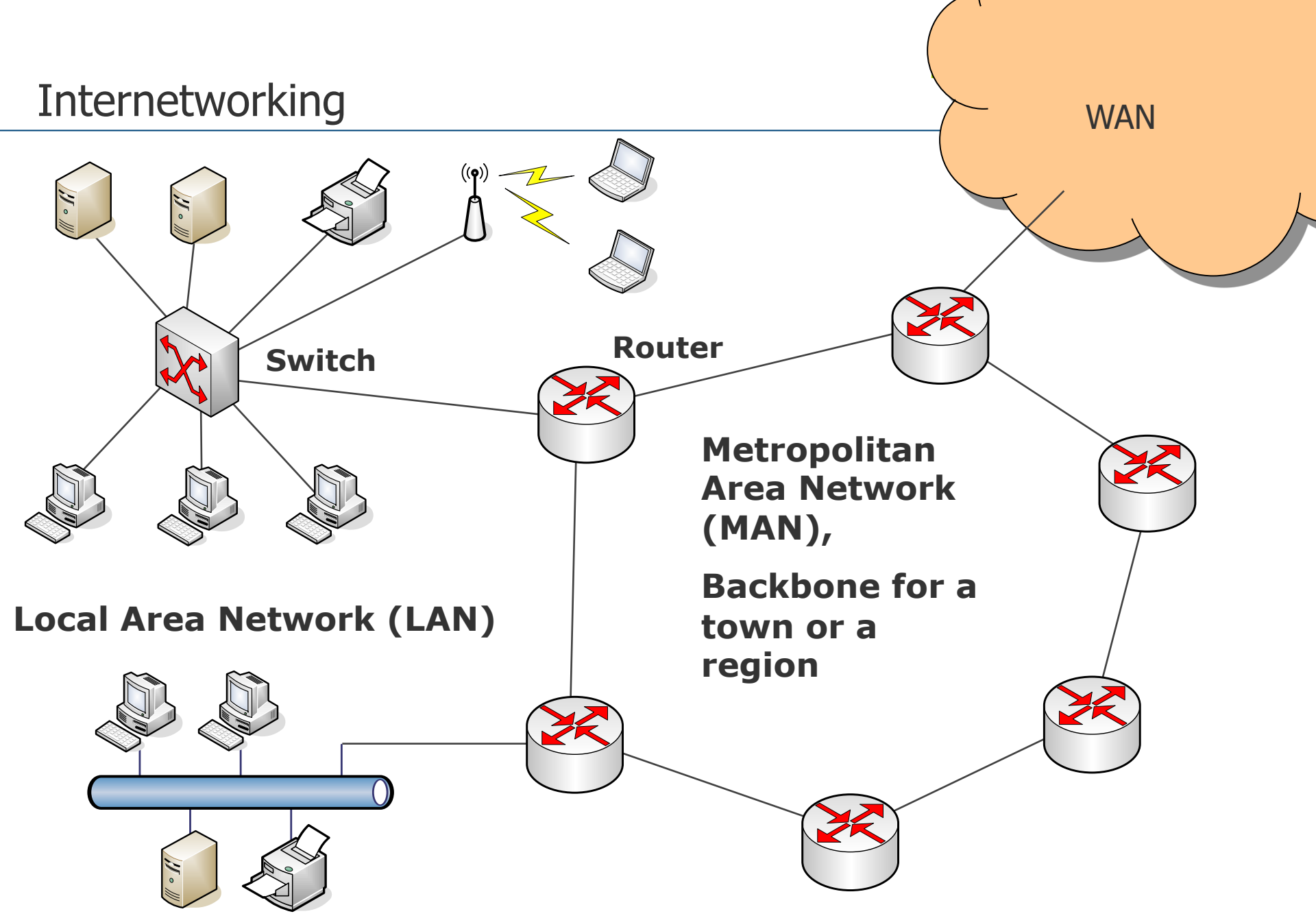
1. Point-to-Point Network
   - One-to-one
     - e.g. a pair of computers is directly connected by one cable



2. Broadcast (or Shared) Network
   - One-to-all
     - Examples: radio, television
   - All connected stations share one transmission channel



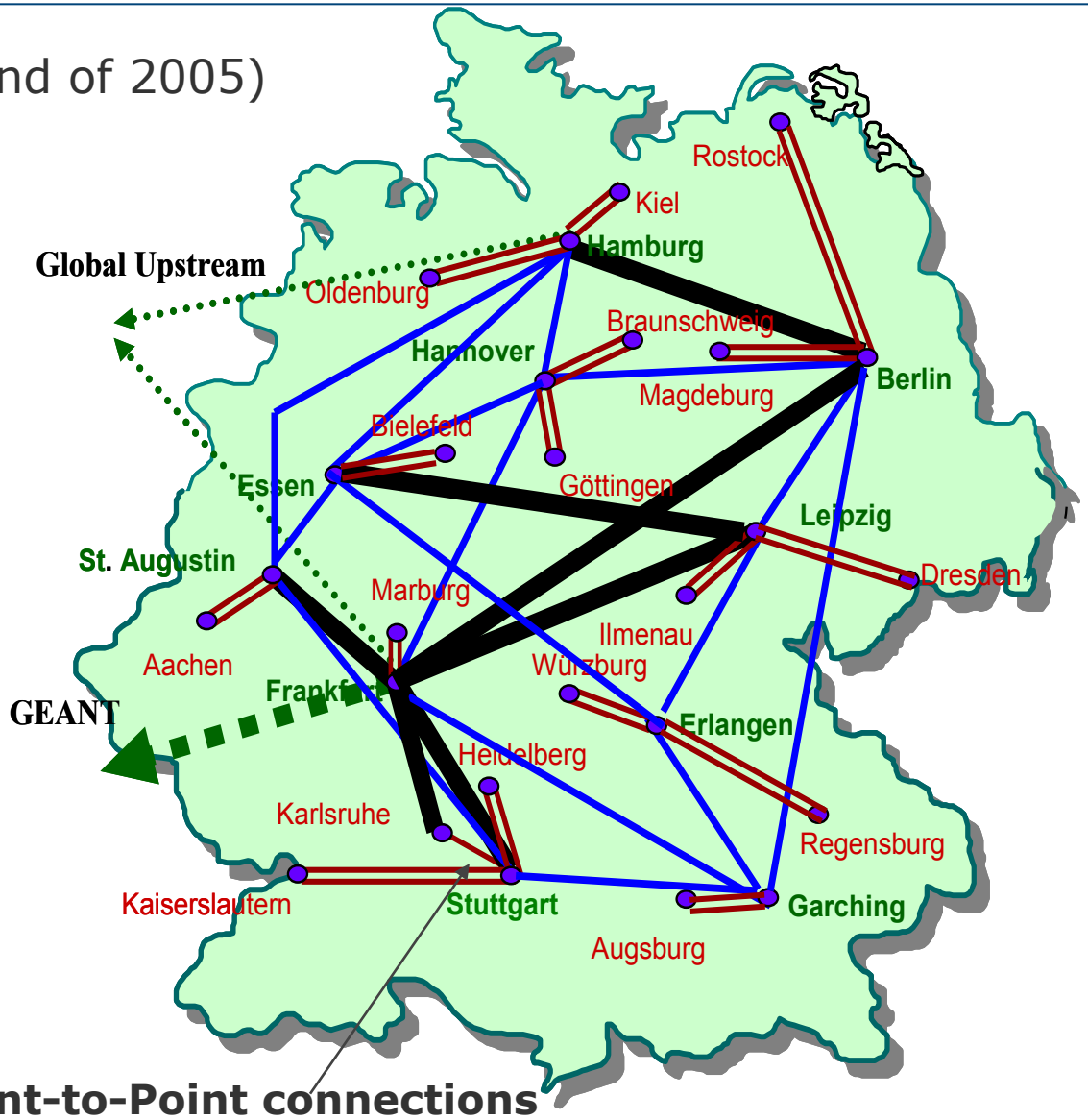
Internetworking



Example of Network: German Backbone

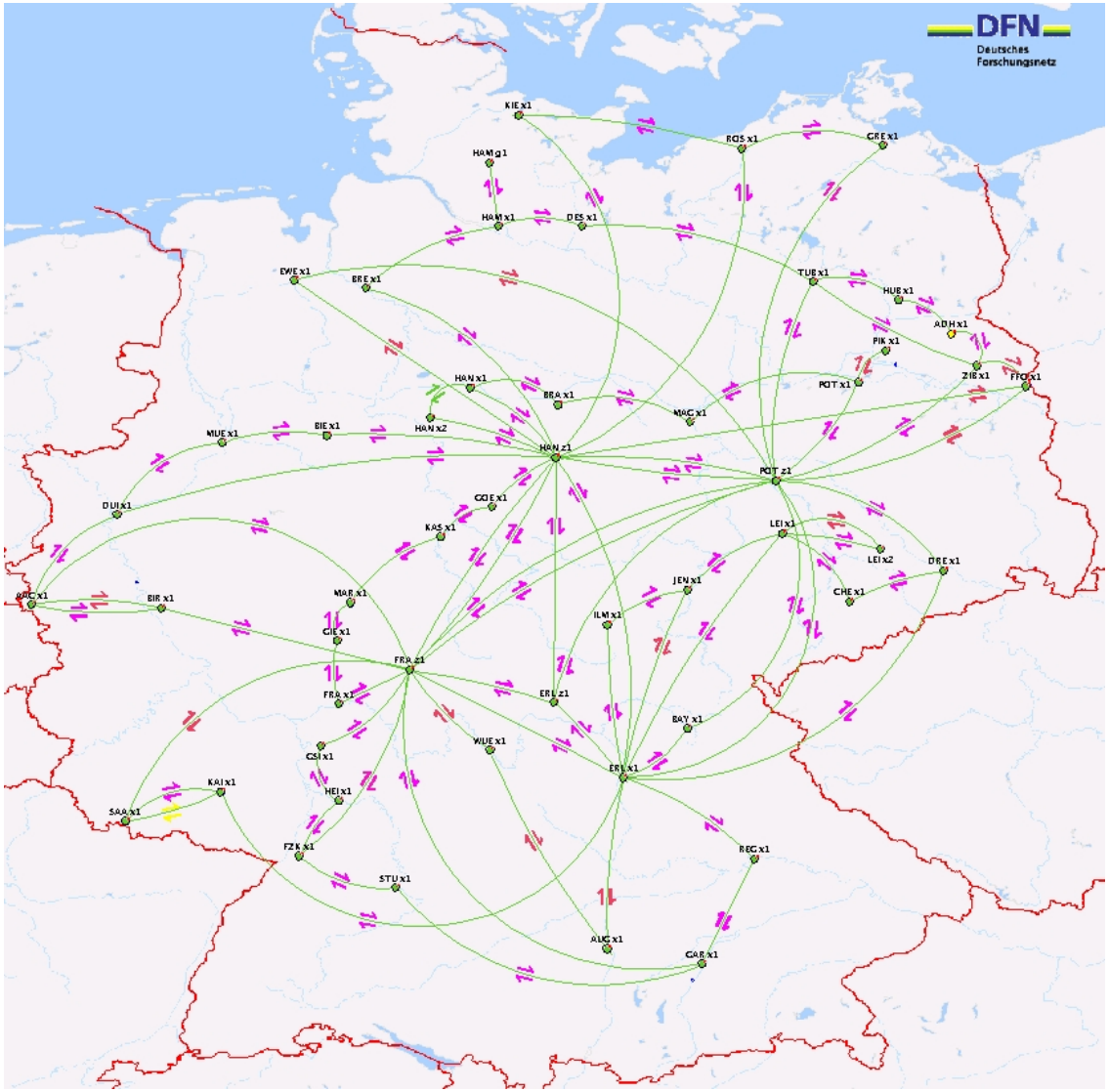
Backbone in Germany (till end of 2005)

27 nodes
10 Gbps
2,4 Gbps
2,4 Gbps



Example of Network: Upgraded German Backbone

- Research backbone in Germany since 2006
  - Since 2006 X-WIN
  - More than 50 nodes
  - Capacities
    - 100Mbps
    - 200Mbps
    - 1Gbps
    - 10Gbps
  - Connected to the European Backbone GÉANT

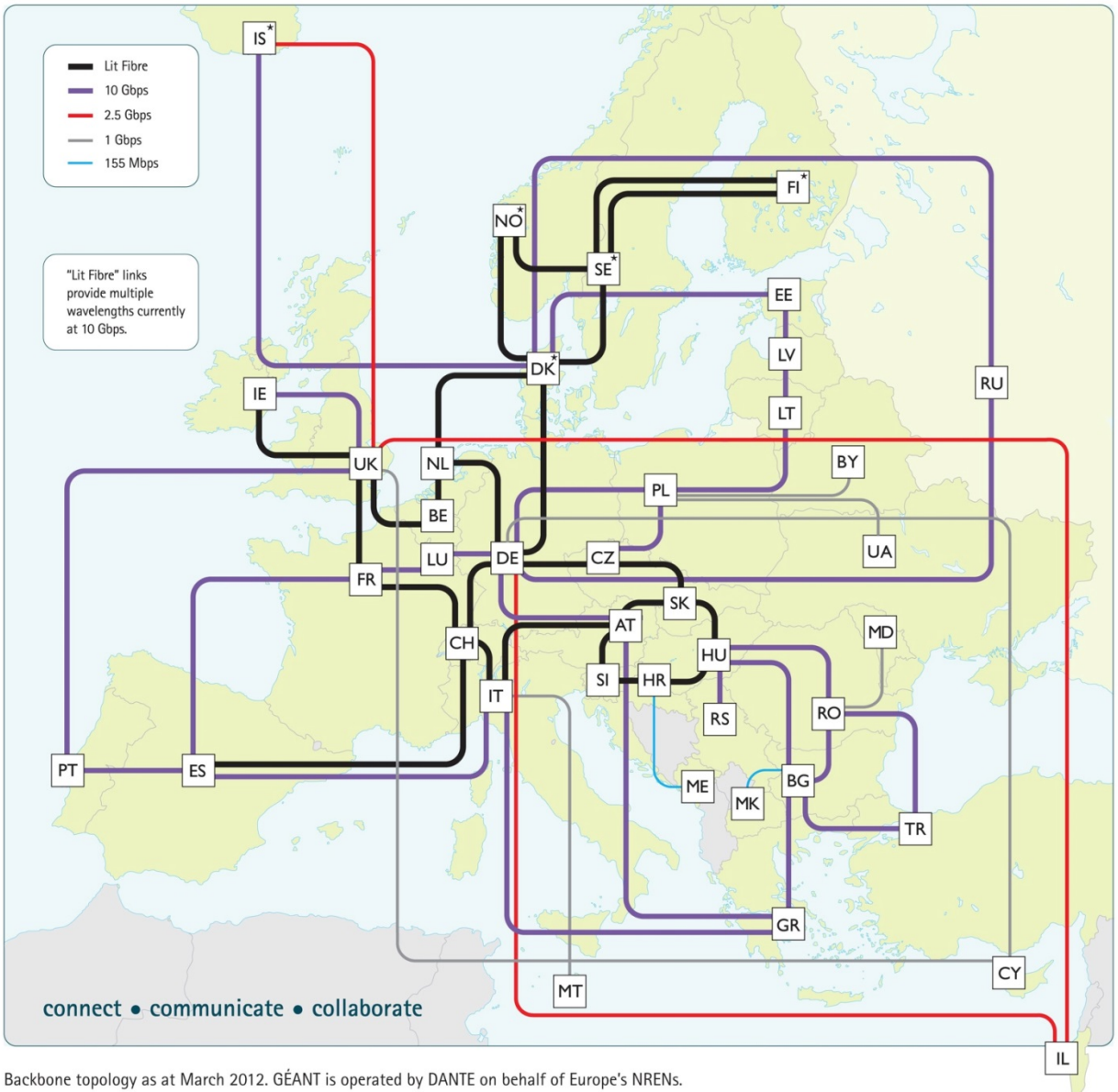


Example of Network: The Géant European Backbone

Through central node Frankfurt : connection to the European research network Géant.

In some nodes (e.g. Frankfurt, Hamburg) there are also intercontinental connections.

It is the Géant Network that connects the FU network to the Internet



Backbone topology as at March 2012. GÉANT is operated by DANTE on behalf of Europe's NRENs.

Observations on Types of Networks

- Heterogeneous basic elements…
  - Various types of devices (routers, switches, printers, PCs, smartphones …)
  - Various capacities within each type of device (more or less CPU, memory…)
  - Various types of links between devices (wire, fiber, wireless)
  - Various capacities within each type of link (1-10G fiber, 802.11b vs 802.11n…)

- But homogeneous services available on the Internet!
  - Voice over IP
  - Video streaming
  - Web browsing
  - Email access

- Communication between arbitrarily different devices, through arbitrarily different intermediate devices and communication mediums
  - **How is this done**?

Designing the Internet

Solution 1

- Write **a single, large program** which fulfills all requirements needed to establish a communication process.
- Advantage: efficient data exchange for a given application.
- Disadvantage: **no flexibility**! Adoptions require large efforts.

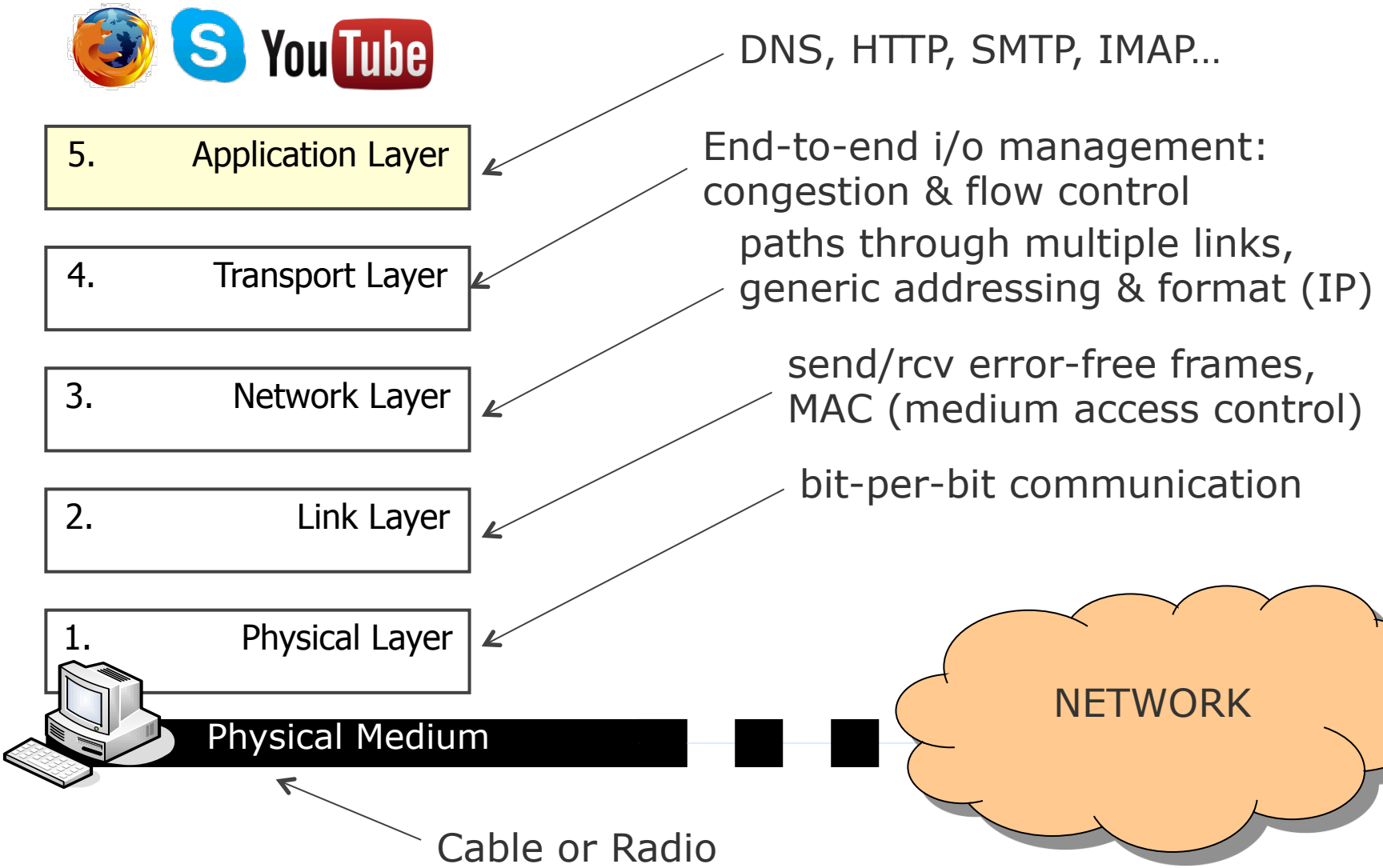
Solution 2

- Break down the communication process into sub-tasks, write **a set of small programs** for each task. Applications use a combination of such programs.
- Advantage: **Very flexible**, since single components can be exchanged.
- Disadvantage: complexity/overhead, performance maybe suboptimal

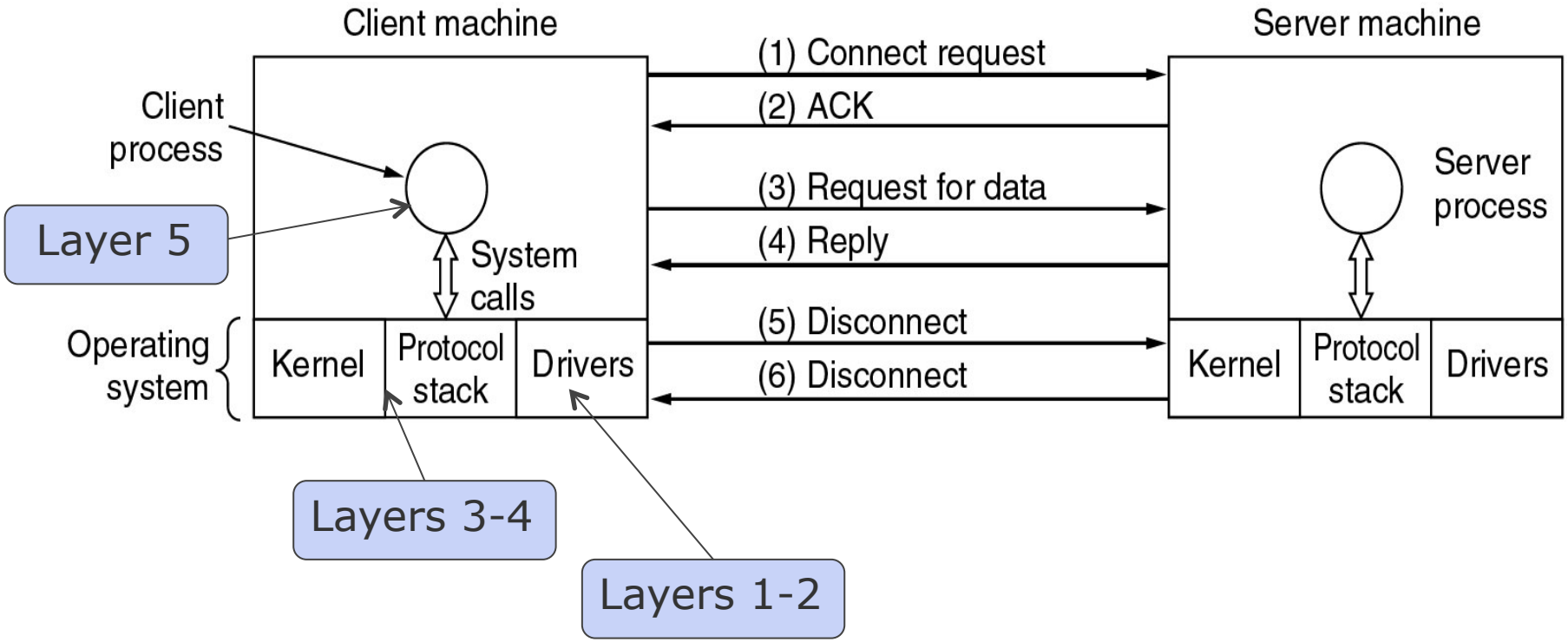
Internet's design

- Uses **Solution 2**, i.e. smaller programs combined based on the *layer model*

Internet: Layer Model



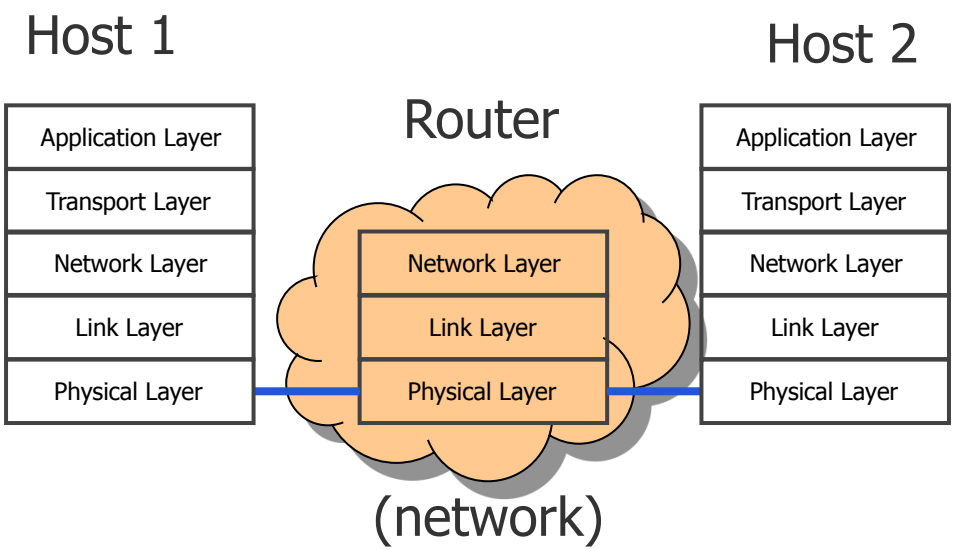
Where in Real-Life Operating Systems?



- Usually the protocol stack is located in kernel of the OS (e.g. Linux)
- But in some cases it is outside of the kernel (e.g. RIOT, microkernel)
- In some cases it is partially outside (e.g. AODV implementation)

Routers and Hosts

- Hosts = End systems, hosting user applications.
  - Implement whole stack.
- Routers = Intermediate systems, providing network connectivity.
  - Implement stack up to network layer only.



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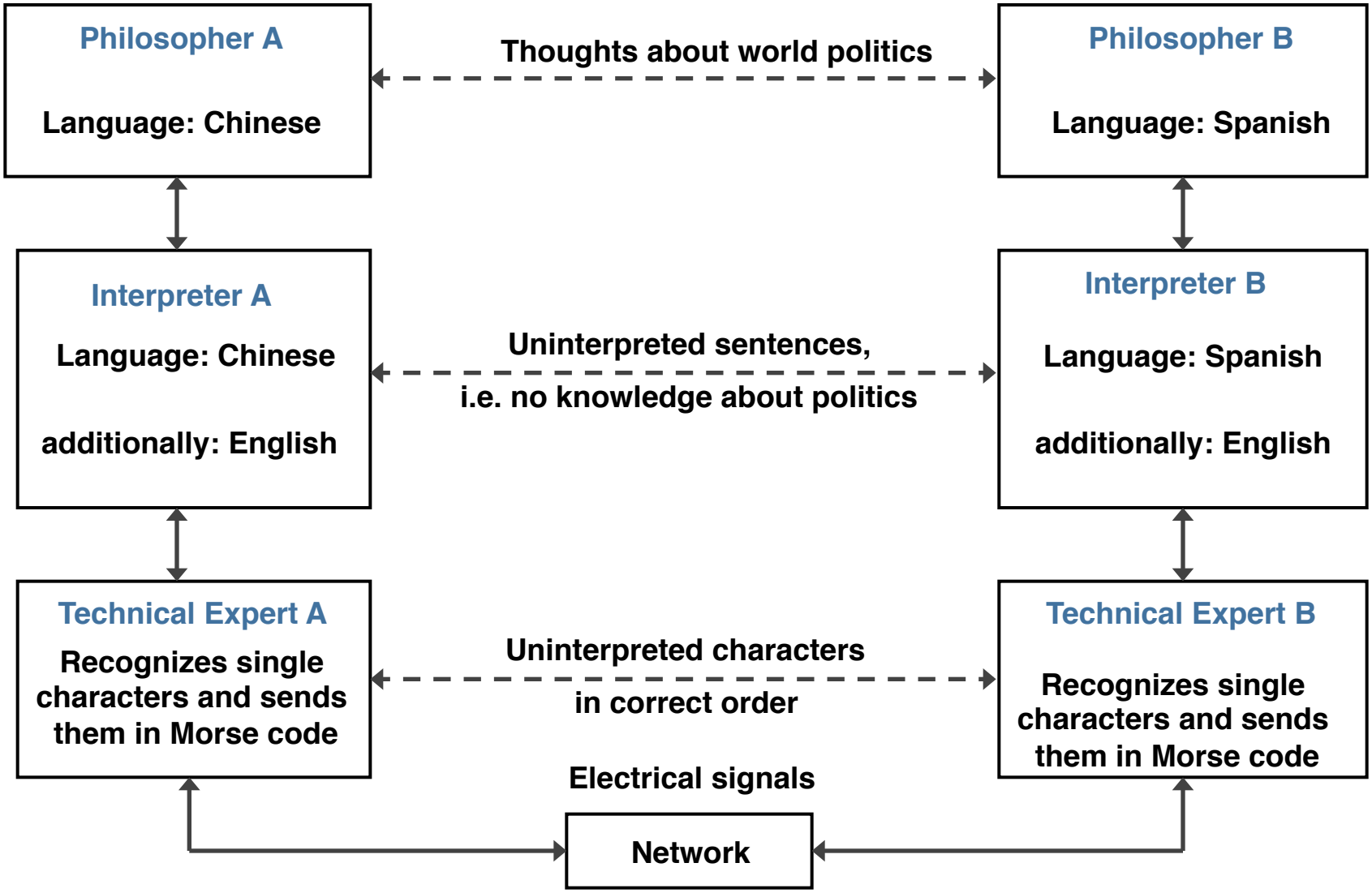
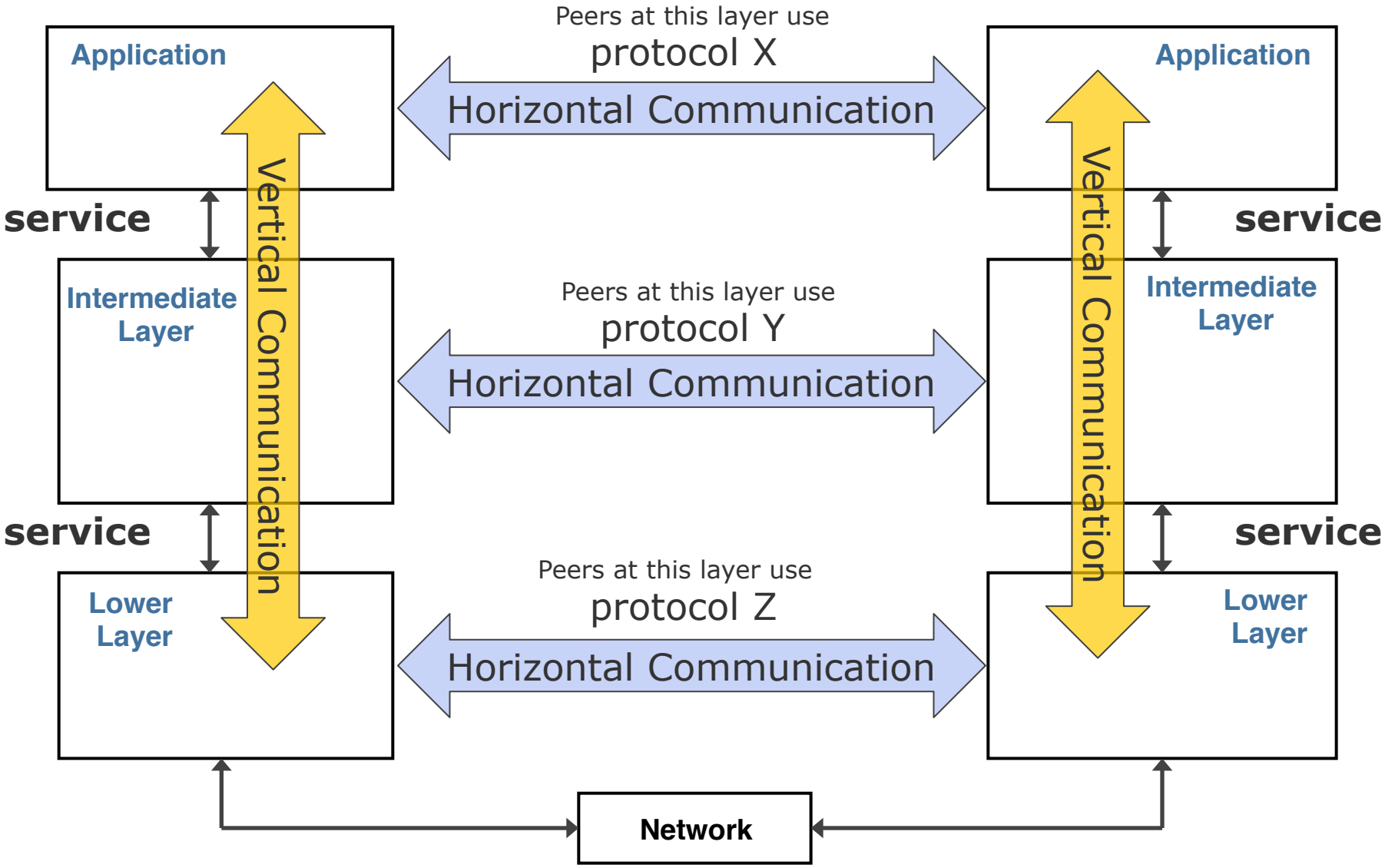
Layers Come from Real-life: Example

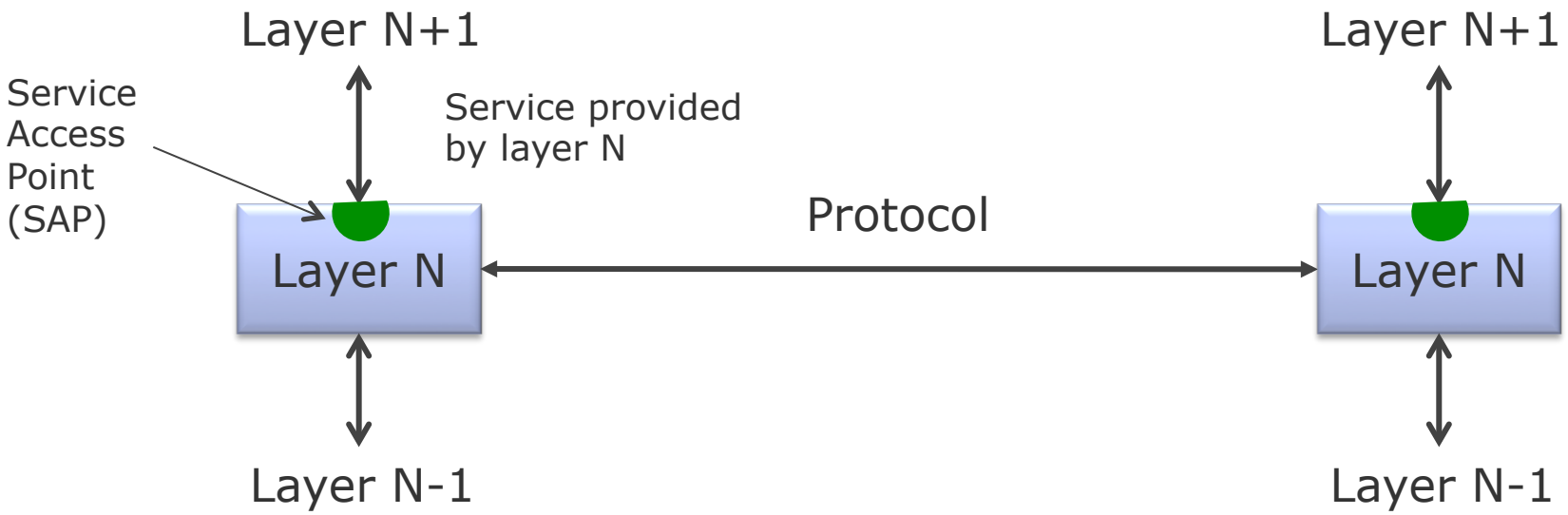


Layers: Services and Protocols



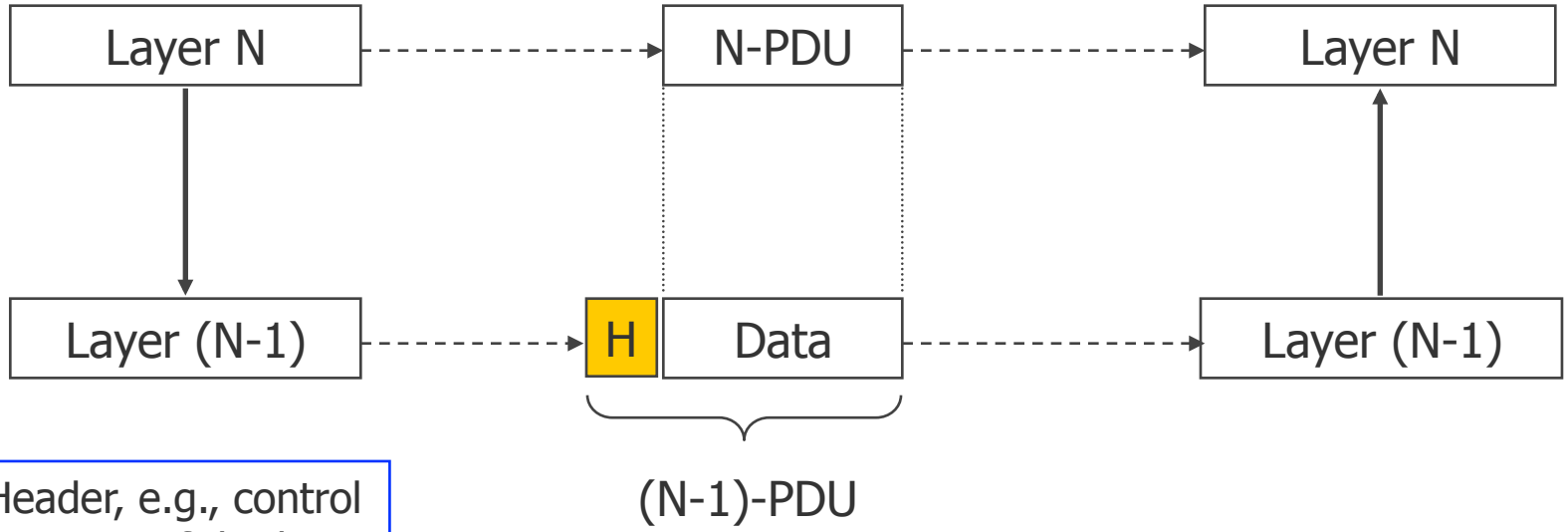
Layers: Upper and Lower Layer Interaction

- Functionality of a layer is offered as a **set of services.**
- The service definition specifies the available services and usage rules.
- The service in a layer is realized by data exchange between **peers**.
- The exchange of data between peers is done according to a **protocol**.



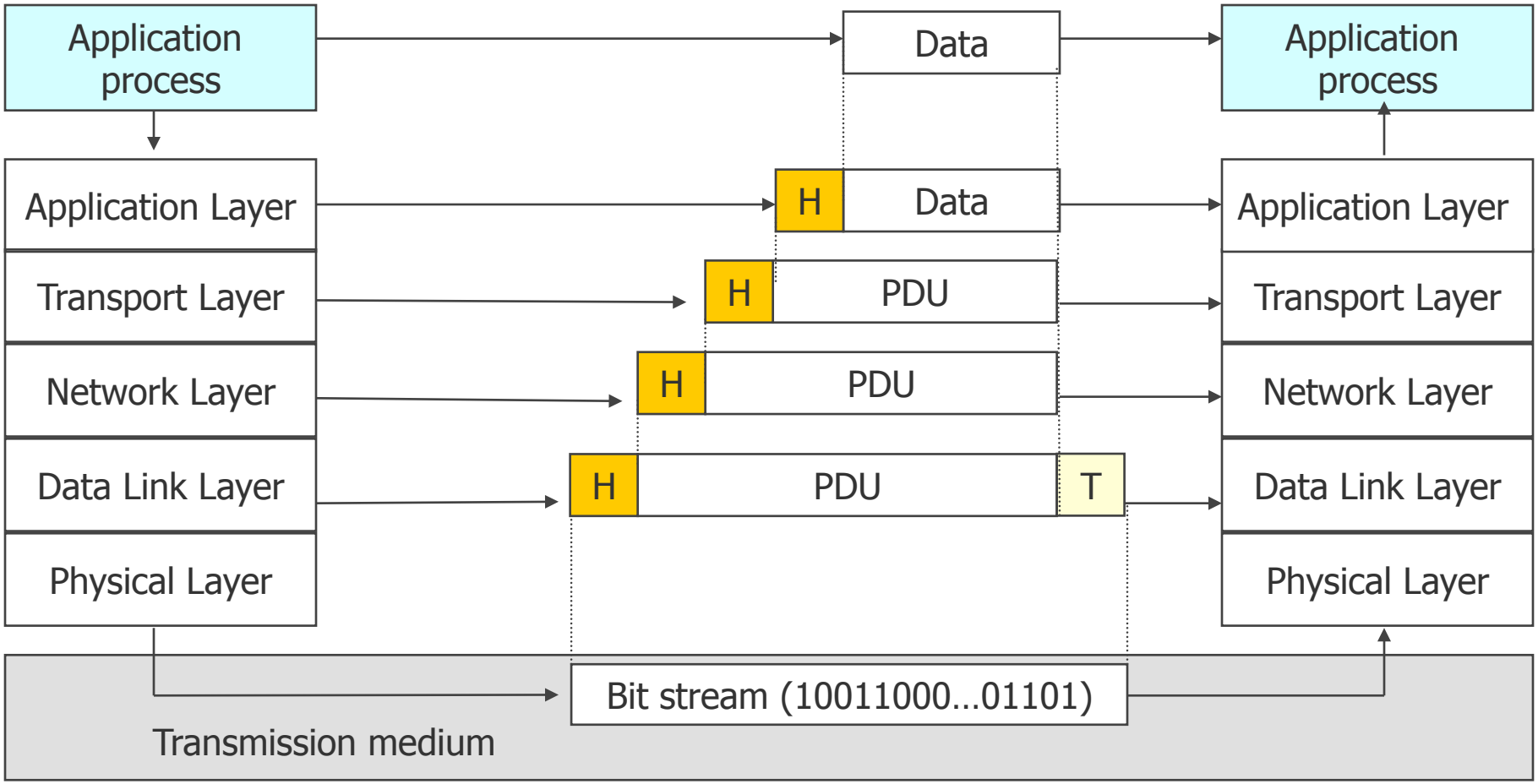
Layers: Upper and Lower Layer Interaction

- Layer (N-1) offers its **functionality** to the above lying layer N as a communication service.
- Layer N enhances the data to be sent with control information (**Header**) and sends the data together with the header as **Protocol Data Units** (**PDU**).
- Two communication partners on layer N exchange PDUs by using the communication service of the lower layer (N-1).
- For layer (N-1), these PDUs are the data to be transmitted.



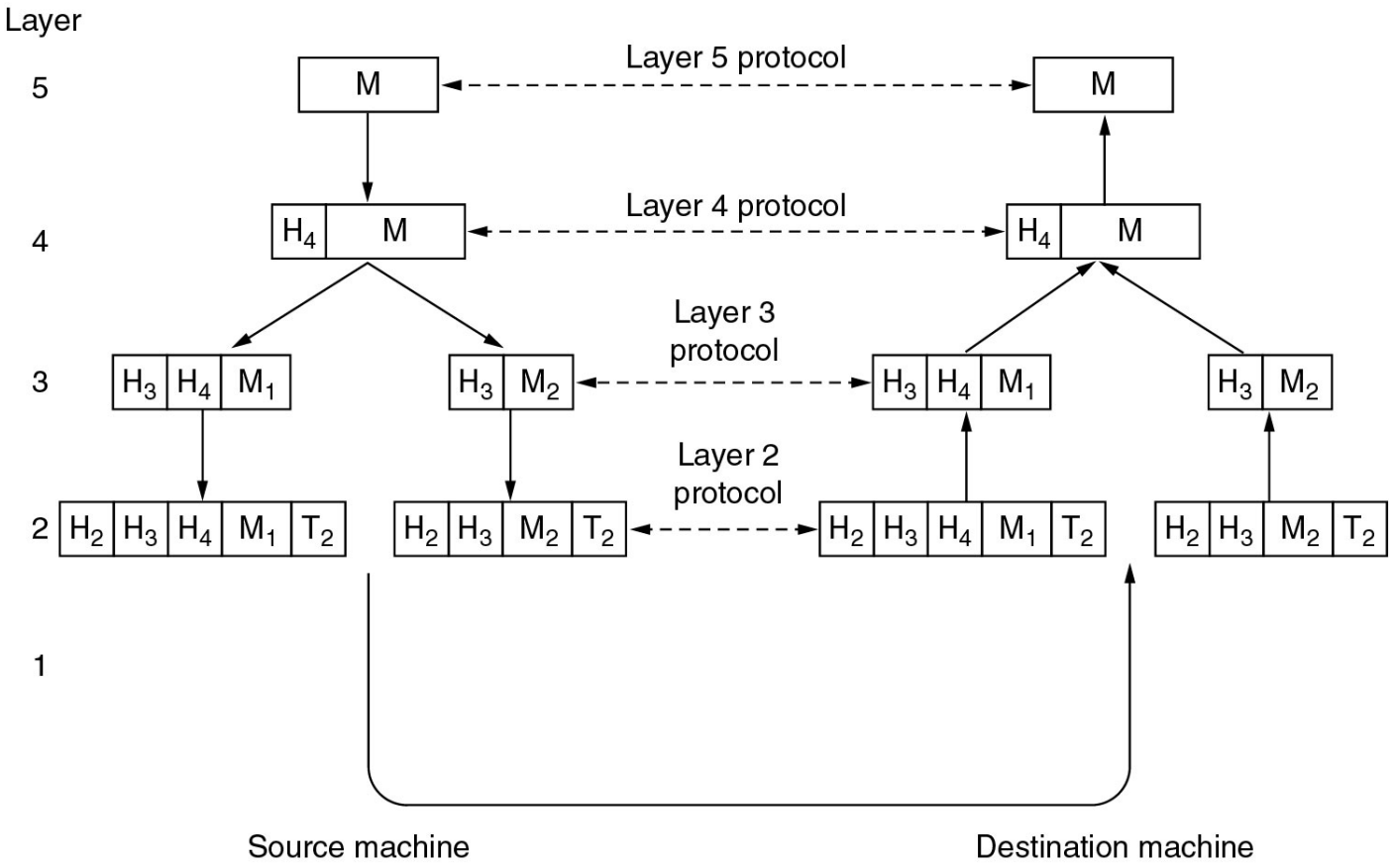
H: Header, e.g., control information of the layer

Layers: Encapsulation, Decapsulation, Multiplexing



Layers: Fragmentation and Reassembly

- Not necessarily a one-to-one PDU mapping between layers
- Depending on the protocol, PDUs can be fragmented before transmission



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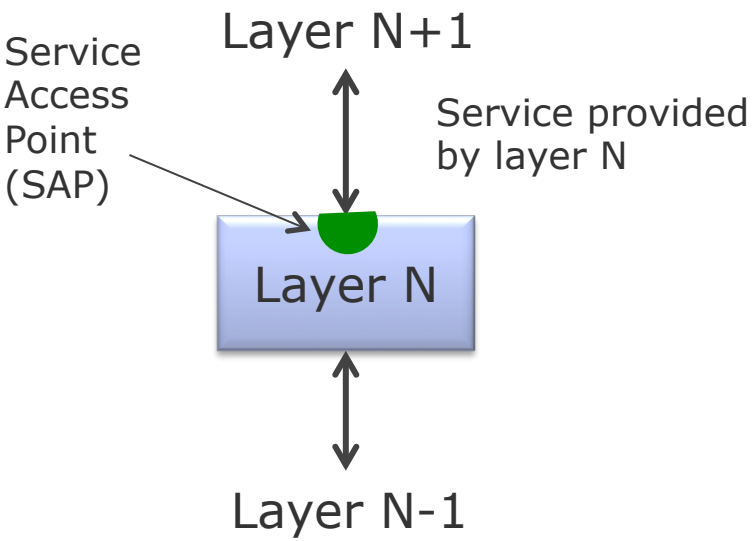
Types of Services

- A service is a specific functionality of a layer N offered to layer N+1

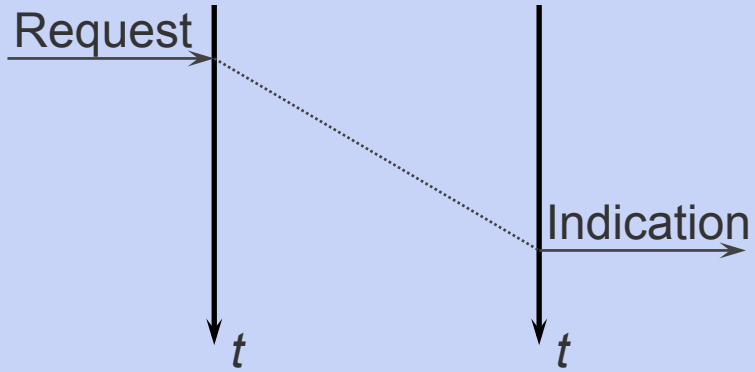


- Types of services are:
  - Request
  - Indication
  - Response
  - Confirmation

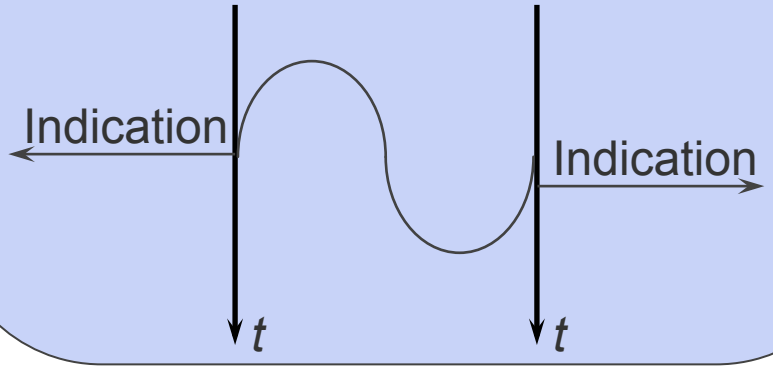
Types of Services: Unacknowledged vs. Acknowledged

Unacknowledged Service

- Initiated by the service user
  - e.g. basic postal service

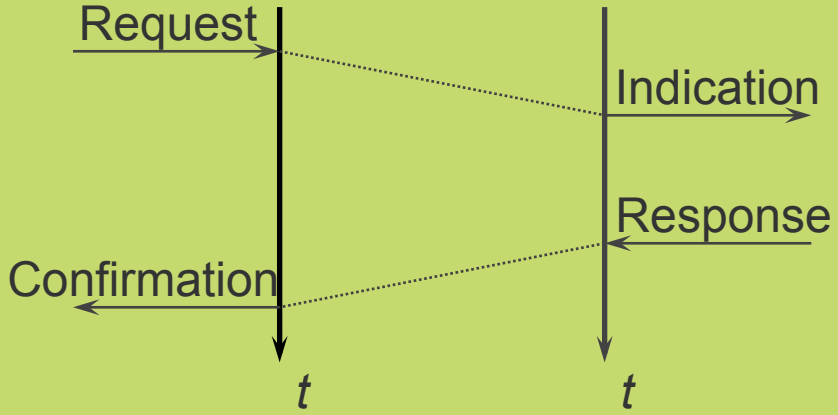


- Initiated by the service provider
  - e.g. phone call cut: busy tone



Acknowledged Service

- Initiated by the service user
  - e.g. premium postal service



Types of Services: Connection-oriented vs. Connectionless

Connection-oriented Service

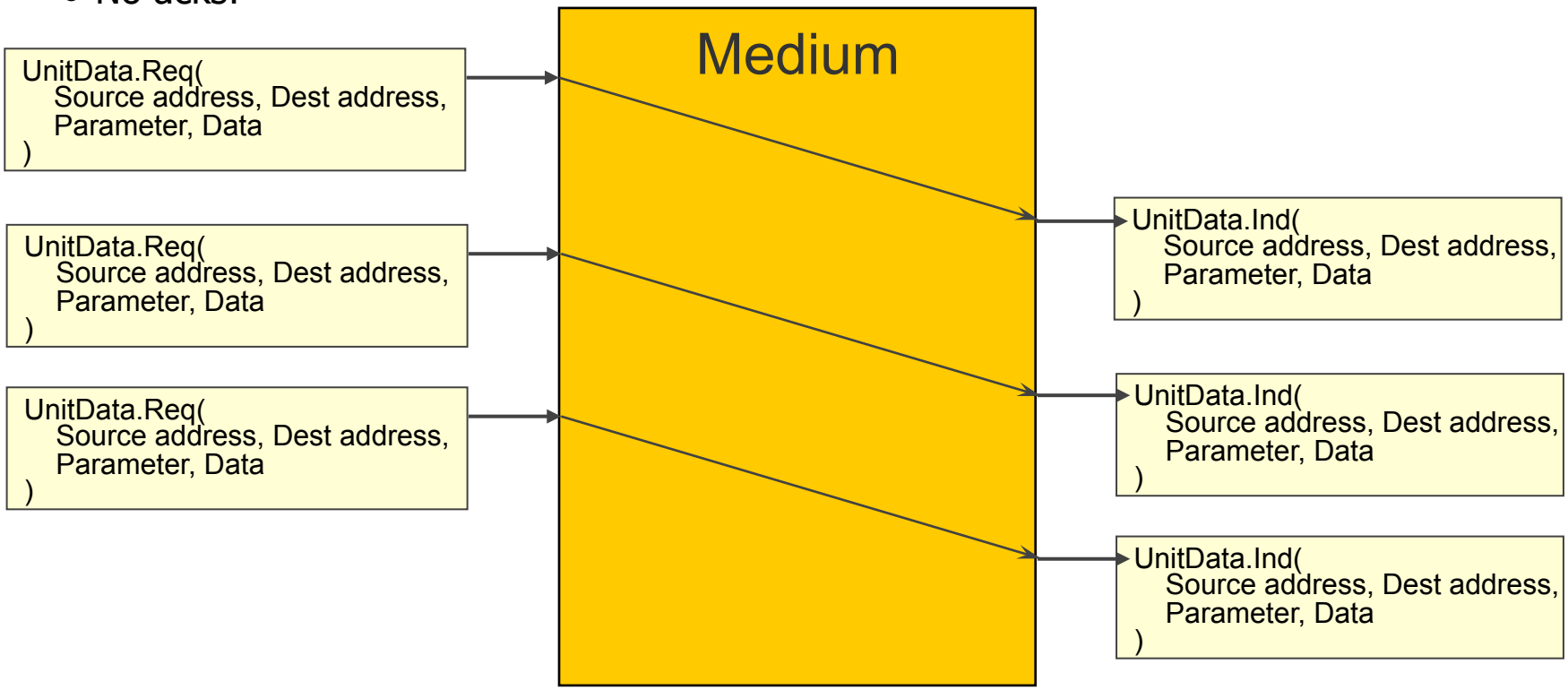
- Modeled after the telephone system
- Before the instances on Layer-(N) can exchange data, a connection on Layer-(N-1) has to be established
  - Request of such a connection is done by the services provided by Layer-(N-1)
- Negotiation of protocol parameters
  - Buffer size
  - Quality of Service (QoS)
  - Routes, etc.
- Exchange of data happens with respect to these parameters
  - Communication context

Connectionless Service

- Modeled after basic postal service
- No establishment of connection on a lower layer required
- Each data exchange is **independent** from others
  - No communication context

Connectionless Service: Overview

- Connectionless Service is also called **Datagram Service**
  - Does not provide relationship between transmissions
  - Does not guarantee the sequence of sent data
  - Does not provide reliability
    - No acks!

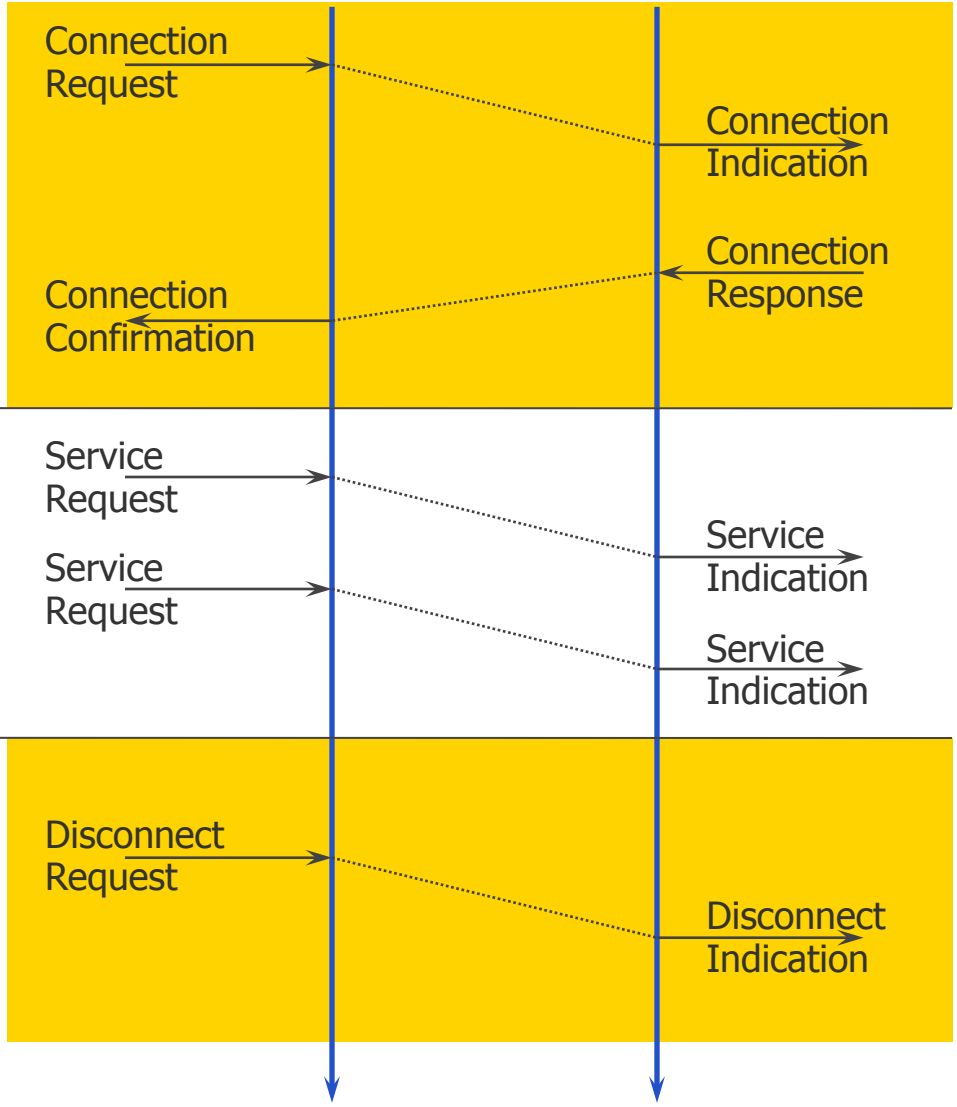


Connection-oriented Service: The 3 Phases

1. Connection establishment
   - Context creation
     - End systems
     - Network

2. Data exchange
   - Data transmission is done within the context

3. Connection termination
   - Context release
   - Resource release



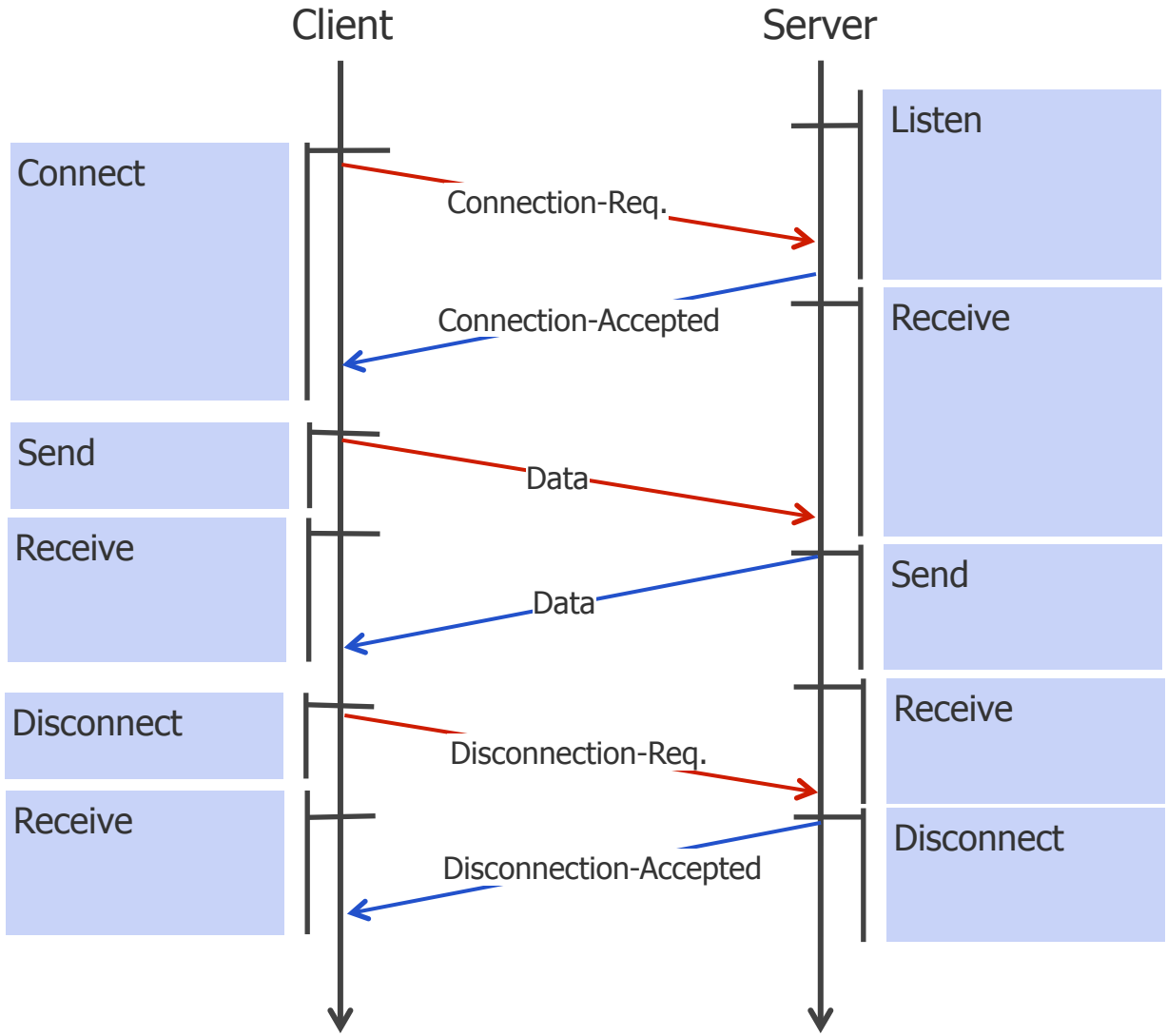
Connection-oriented Service: Service Primitives

- There are five service primitives for a simple connection-oriented service.

Primitive	Meaning
LISTEN	Block waiting for an incoming connection
CONNECT	Establish a connection with a waiting peer
RECEIVE	Block waiting for an incoming message
SEND	Send a message to the peer
DISCONNECT	Terminate a connection

- Primitives are useful to design *finite state machines* for protocol analysis, protocol simulation, verification and testing, or even protocol design.

Connection-oriented Service: Service Primitives



Example Services & Classification

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Remote login
	Unreliable connection	Digitized voice
Connection-less	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Registered mail
	Request-reply	Database query

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Alternative Layer Model: the OSI Reference Model

7	**Application**	Common services for the end user
6	**Presentation**	Network-independent end-to-end data transfer
5	**Session**	
4	**Transport**	
3	**Network**	Addressing and routing of "**packets**"
2	**Data Link**	Securing of "**frames**", Flow Control
1	**Physical**	Signal representation, character transmission

Transmission medium ("Layer 0")

Criticism of the model

Layer 5 and 6 are rarely implemented

Generally too much overhead – some details are unnecessary, some layers are overloaded

Additional Layers: Session and Presentation Layers

- **Session Layer**
  - This layer is intended to manage:
    - reliable data transport between two hosts (End-2-End)
    - Dialogue control
    - Token Management
    - Synchronization points

- **Presentation Layer**
  - This layer manages the representation of data in an platform independent format
    - Some computers code a string with ASCII others use Unicode, some use for integers the 1-complement others the 2-complement.
    - Instead of defining a new transmission syntax and –semantics for every application, the goal is to provide a universally valid solution.
  - Data are encoded in an abstract (and commonly recognized) **data format** before the transmission and are coded back by the receiver into its own data format.

OSI Layers vs. Internet Layers

- Time
  - The TCP/IP protocols were already widely used before OSI had finished its standardization process.
- Freedom from obligation
  - A "reference model" like OSI is free from obligation. It only defines what is to be done, but not how to do it.
    ➡ incompatibility of products.
- Complicatedness
  - Over-specification : thousands of pages "needed" to describe OSI!
  - Too many special cases considered, lots of options included, making the products lavish, unhandy, and far too expensive
    ➡ "The option is the enemy of the standard"!

OSI Layers vs. Internet Layers

- Political reasons
  - OSI was dominated too much by Europe – especially from the national telecommunication companies which had lucrative monopolies. The real market power was in the USA – nobody was interested in OSI over there.
- Hurriedly product implementation
  - The first OSI products were implemented too fast (driven by the success of TCP/IP protocols), were covered with faults, and had an overall low performance.
  - In contrast, the "theoretically far more unmodern" TCP/IP protocols were continuously modified and improved. They were of high quality level and successfully tested before deployment and cheap to buy due to high production numbers.

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Standardization

- Standardization is necessary, especially for communication systems
  - Goal: **interoperability** in order to enable resource sharing
  - Standardization needed on national as well as international level

- Successful standardization is a challenge because:
  - Complex technical problems have to be solved
  - The involved parties, e.g., companies are often working against each other
  - Confidentially restrictions slow down/hinder the information flow

- Consequence
  - Standardization processes are slow (due to many, often non-technical reasons)
  - Sometimes proprietary solutions take over fast
    - e.g. Skype
  - But sometimes it's obviously better to have standards
    - e.g. cellular networks: let's not change our cell phone depending on access point!

Standardization: The Global Players

- ITU www.itu.int
  International Telecommunication Union
  United Nations agency for information and communication technologies
  - Radiocommunication (ITU-R)
  - Telecommunication Standardization (ITU-T)
  - Development (ITU-D)
- ISO www.iso.org
  International Organization for Standardization (ISO Greek "uniform")
  - ISO coordinates the standardization except from PTT
- W3C http://www.w3.org
  - World Wide Web Consortium: Develops standards for the web.
- DIN www.din.de
  (Deutsches Institut für Normung,)
  - German partner of the ISO
  - Famous for european standard for A4 paper size!

Standardization: ISO

- **International Organization for Standardization (ISO)**
  - Since 1946
  - Working on a volunteer basis
  - Members: standards organizations of approx. 90 countries
  - Deals with a **very** broad range of standards
  - 200 Technical Committees (TC) for specific tasks (e.g. TC97 for computer and information processing)
  - TCs consist of subcommittees comprising in turn several working groups
  - Works hand in hand with ITU-T regarding telecommunication standards, (ISO is a member of ITU-T).
  - **Pioneering work of ISO regarding data communication: the ISO/OSI reference model**
    - Open Systems Interconnection (OSI)
  - Notice: only the concept is pioneering, not the products developed from those concepts!

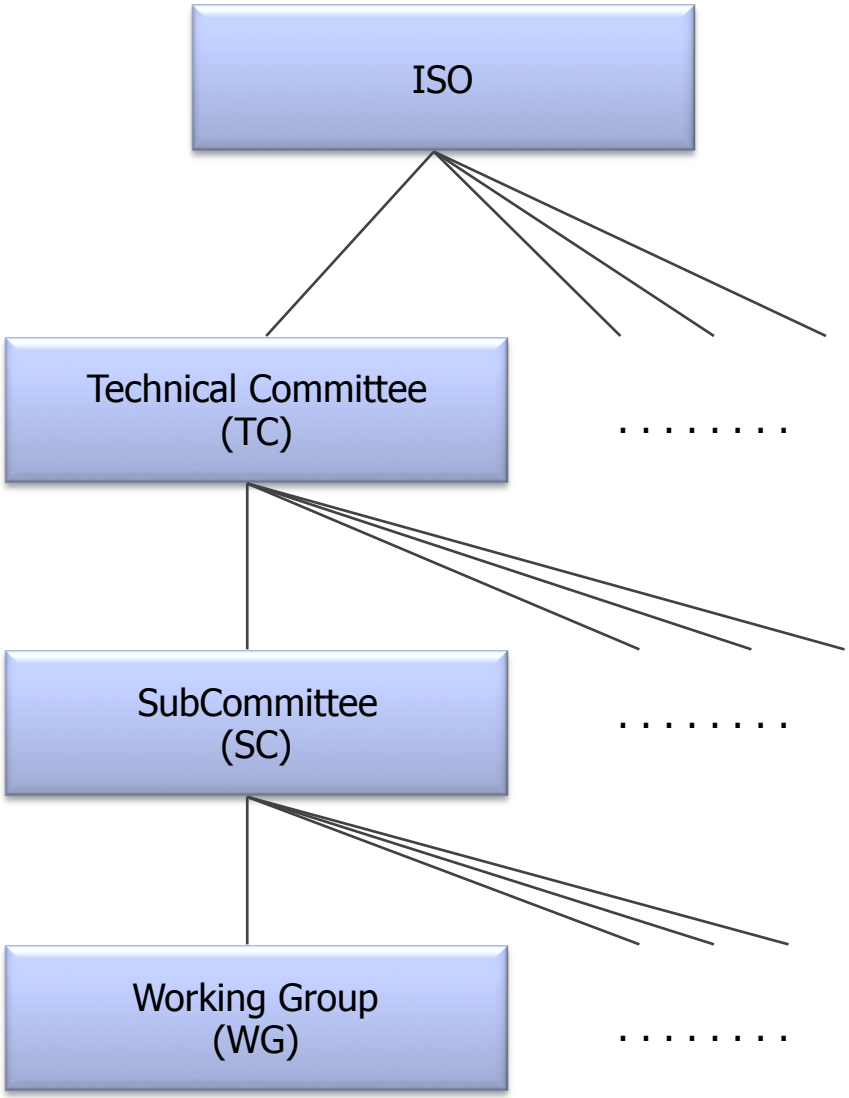
International Organization for Standardization

www.iso.org

Standardization: ISO

- WG-Meetings:
  - Every 6-9 months to give the national organizations time to check the proposals.
  - The process of standardization
    - DP: Draft Proposal
    - DIS: Draft International Standard
    - IS: International Standard
  - A proposal gets higher in the hierarchy after an international vote and the incorporation of critics.

➡ A very slow process!!!



Standardization: IETF

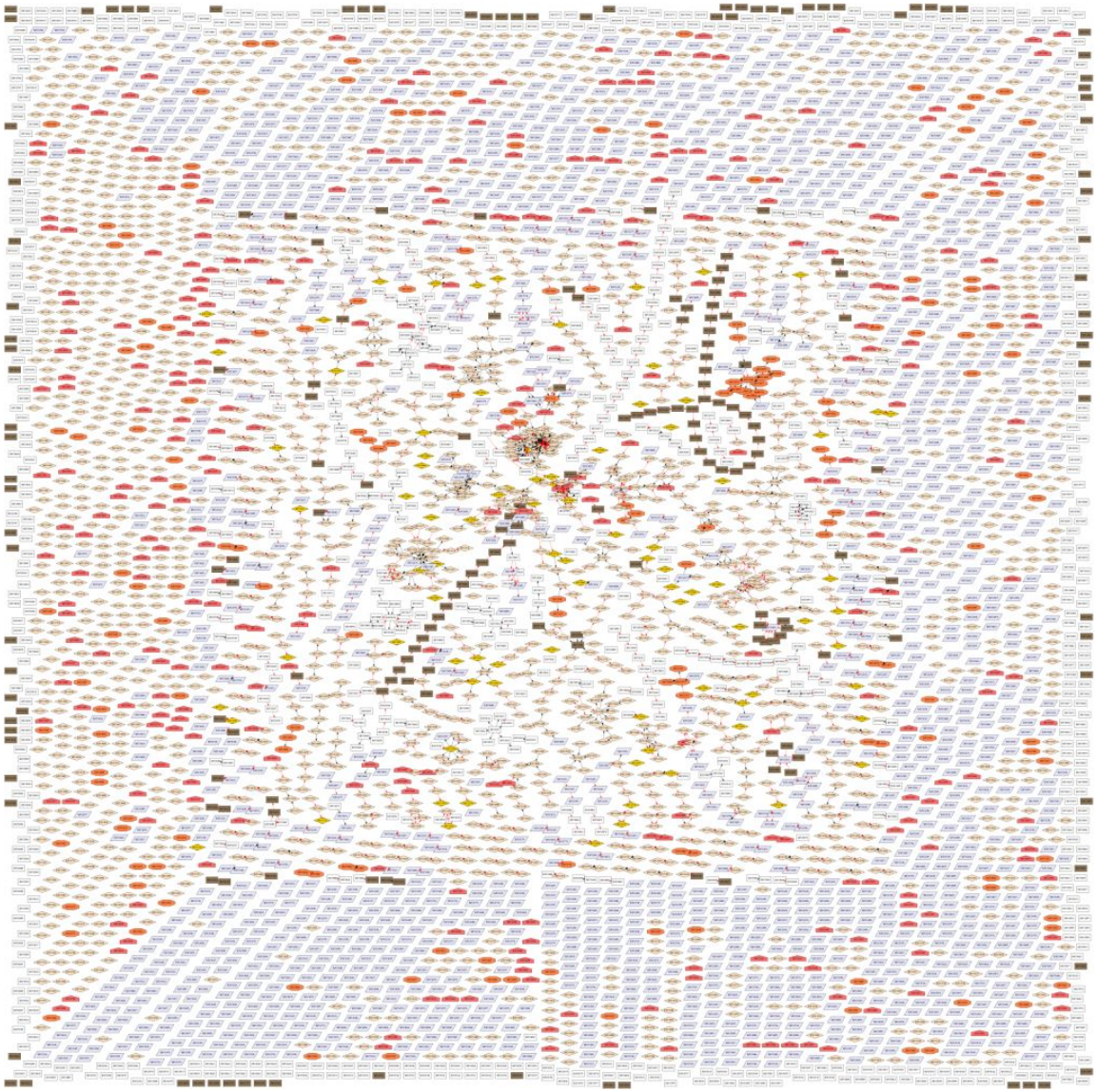
- **Internet Engineering Task Force (IETF)**
  - Since 1986
  - Forum for the technical coordination of the work regarding the Internet (previously ARPANET).
  - Gathers a large, **open**, and international community of administrators, vendors, researchers and… simple **individuals**.
  - Publishes and maintains developer-friendly specifications in documents called Request For Comments: RFC
    - for instance TCP was first specified in RFC 793
  - Before becoming an RFC, a specification must mature as an Internet Draft
    - Not all drafts become an RFC
    - Multiple draft stages until RFC status (see RFC 2026)
    - RFC completion-time unit = year(s)
  - Focus on evolution of Internet architecture & smooth operation of the Internet.
  - Split in areas: applications, routing, security, transport…
  - Each area split in working groups. IESG coordinates, under IAB oversight.
  - Result of such a standardization process: the resounding success of the Internet protocols TCP/IP

I E T F

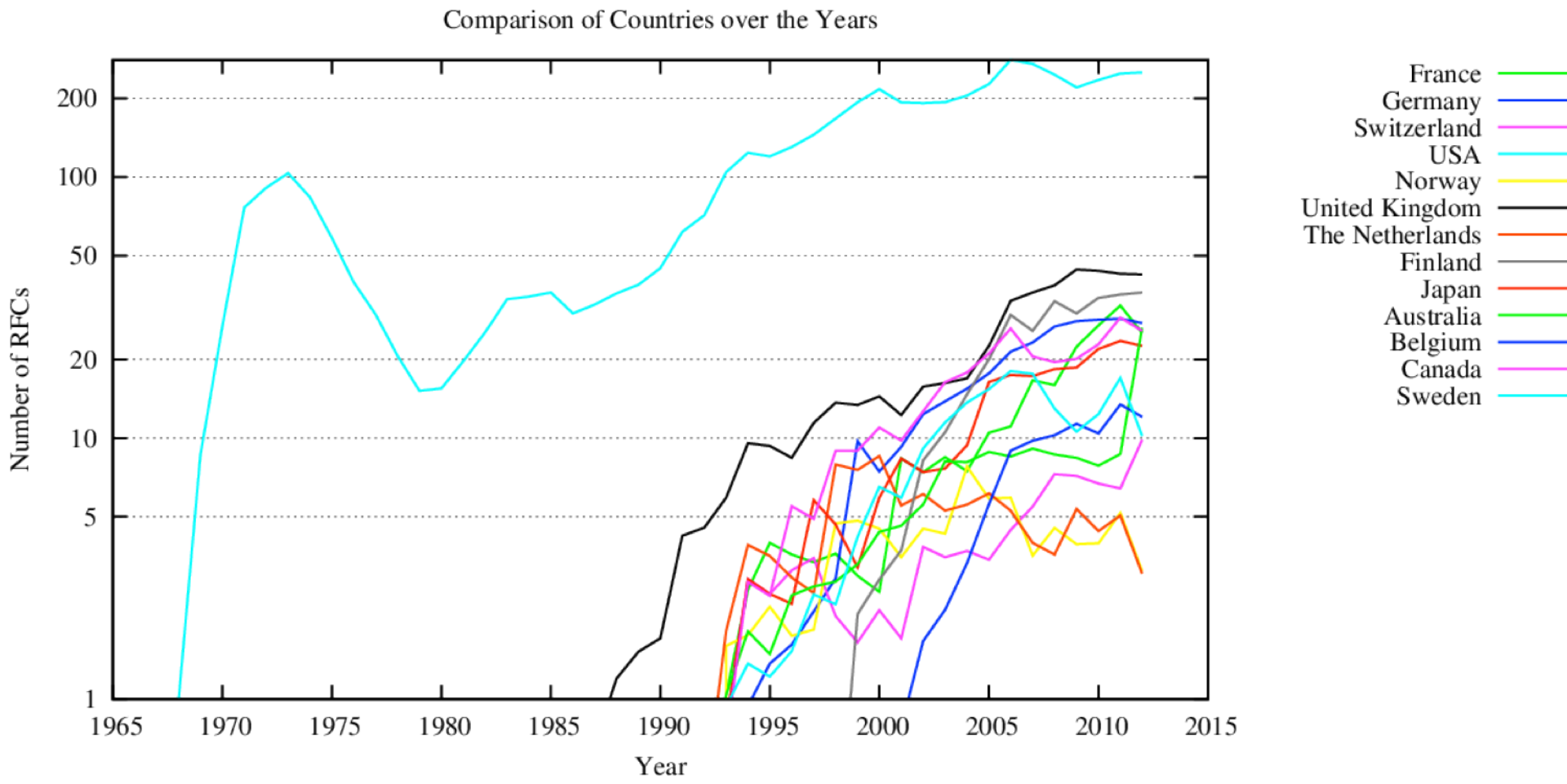
www.ietf.org

Standardization: Internet

Relationship of all RFCs (from 2010)



Standardization: Internet



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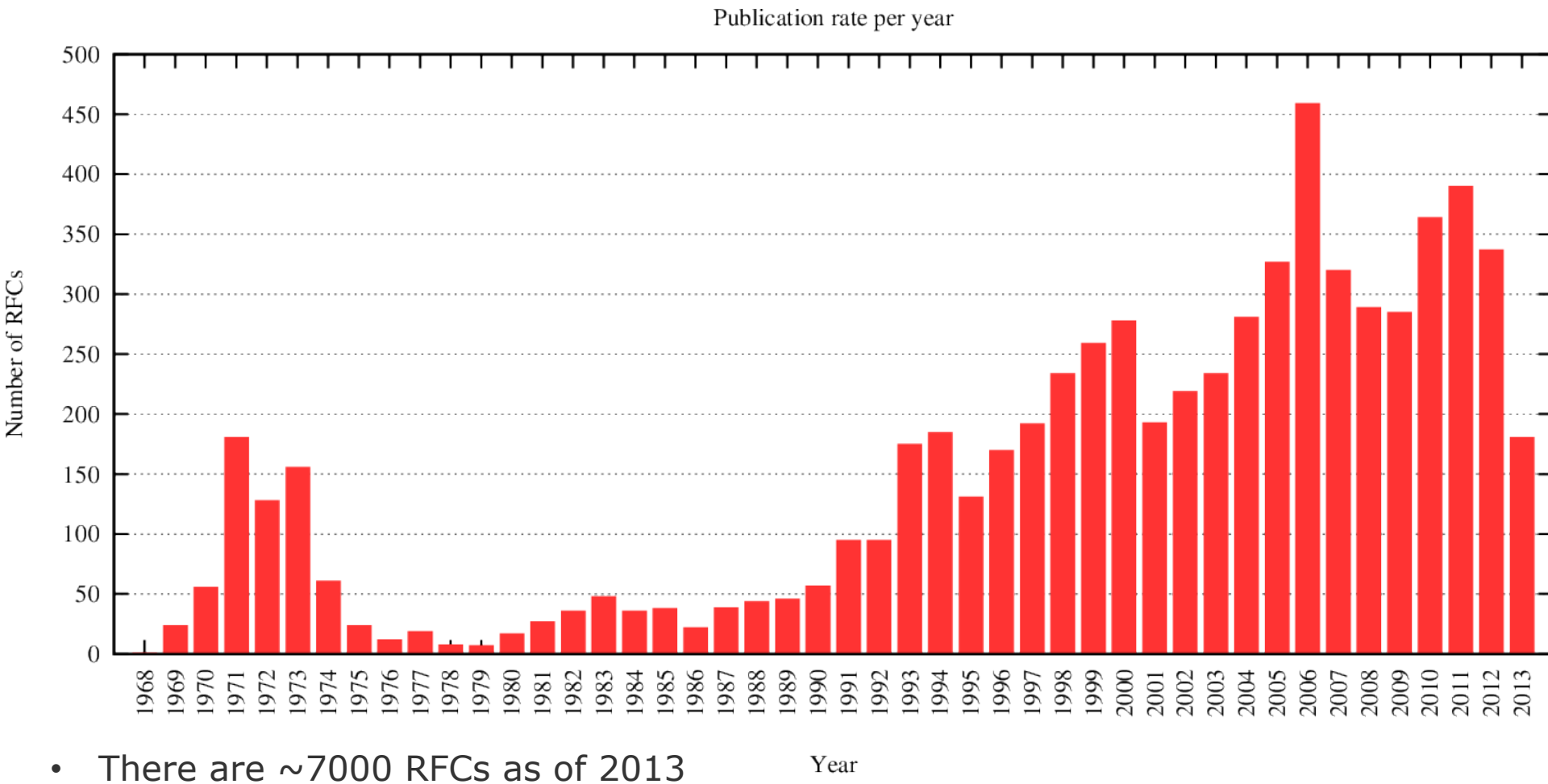
Standardization: Internet



Source: http://www.arkko.com/tools/docstats.html

- There are ~7000 RFCs as of 2013
- The Internet Engineering Task Force: www.ietf.org
- Homepage of RFC Editor: www.rfc-editor.org
- IETF Tools: http://tools.ietf.org

Standardization: IEEE

- **Institute of Electrical and Electronic Engineers (IEEE)**
  - Since 1963. Professional association with 430k members
  - Standardization e.g. of the IEEE 802.X-Standards for Local Area Networks (www.ieee802.org, grouper.ieee.org/groups/802/dots.html)

www.ieee.org

- 802.1 Overview and Architecture of LANs
- 802.2 Logical Link Control (LLC)
- 802.3 CSMA/CD (Ethernet)
- 802.4 Token Bus
- 802.5 Token Ring
- 802.6 DQDB (Distributed Queue Dual Bus)
- 802.7 Broadband Technical Advisory Group (BBTAG)
- 802.8 Fiber Optic Technical Advisory Group (FOTAG)
- 802.9 Integrated Services LAN (ISLAN) Interface
- 802.10 Standard for Interoperable LAN Security (SILS)
- 802.11 Wireless LAN (WiFi)
- 802.12 Demand Priority (HP's AnyLAN)
- 802.14 Cable modems
- 802.15 Personal Area Networks (PAN, Bluetooth, Zigbee)
- 802.16 Wireless MAN (WiMAX)
- 802.17 Resilient Packet Ring
- 802.18 Radio Regulatory Technical Advisory Group (RRTAG)
- 802.19 Coexistence Technical Advisory Group
- 802.20 Mobile Broadband Wireless Access (MBWA)
- 802.21 Media Independent Handover

Course Organization

- The Internet as a Blackbox: Applications
  - Basic terminology & concepts (protocols, API…)
  - Dive into DNS, Email, HTTP, SNMP & their interface to the blackbox
- Opening the Blackbox: The IP Protocol Stack
  - Basic terminology & concepts (layers, standard stack…)
  - Dive into each layers
- New trends in the domain of computer networks