Technische Universität Berlin

Rechnernetze

Protokolle

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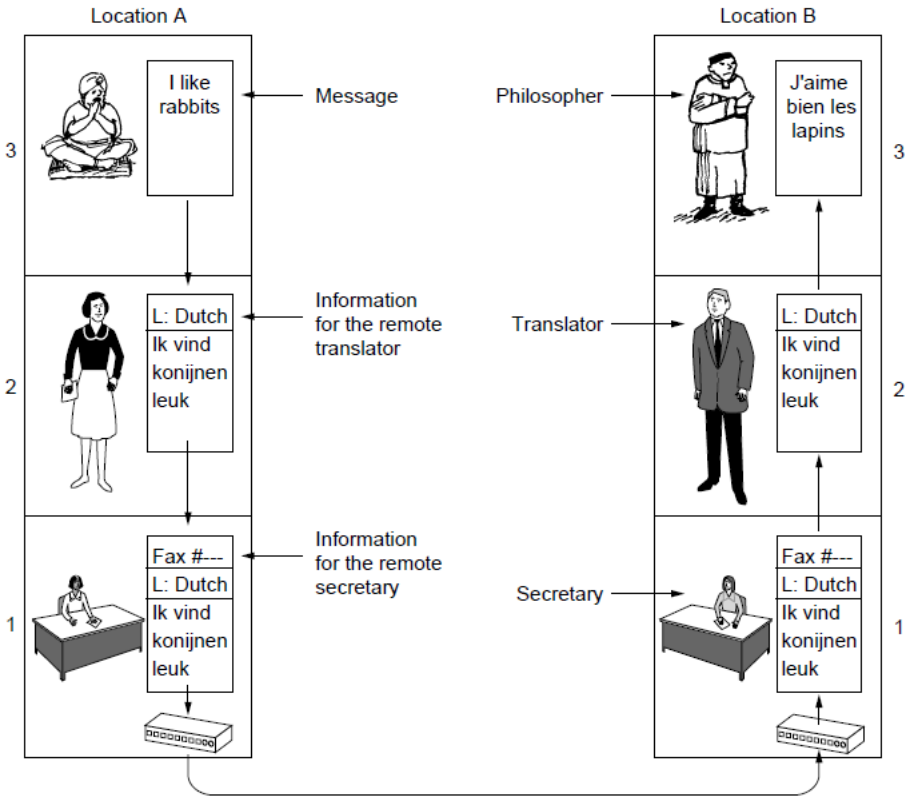
- Rechnernetze sind „ziemlich“ komplex
  - Endgeräte, Switches, Router, Schnittstellenkarten, Leitungen, Kanäle, Verbindungen
  - Nachrichten
  - Mechanismen zur Fehlersicherung, Fluss- und Überlastkontrolle, Adressierung, Wegsuche, Weiterleitung, Medienzugriff, …
- Protokolle
  - wesentliches Strukturierungsprinzip
  - legen **Nachrichtenformat** und **Verhalten** der Kommunikationspartner fest
  - Beispiel: Hypertext Transfer Protocol (HTTP)
    - HTTP-Client erfragt Inhalte von HTTP-Server
    - 2 Arten von Nachrichten: Anfrage und Antwort
    - festgelegte Formate beider Nachrichten
    - festgelegtes Verhalten von HTTP-Client und HTTP-Server

Analogy: The philosopher-translator-secretary architecture

Philosophers

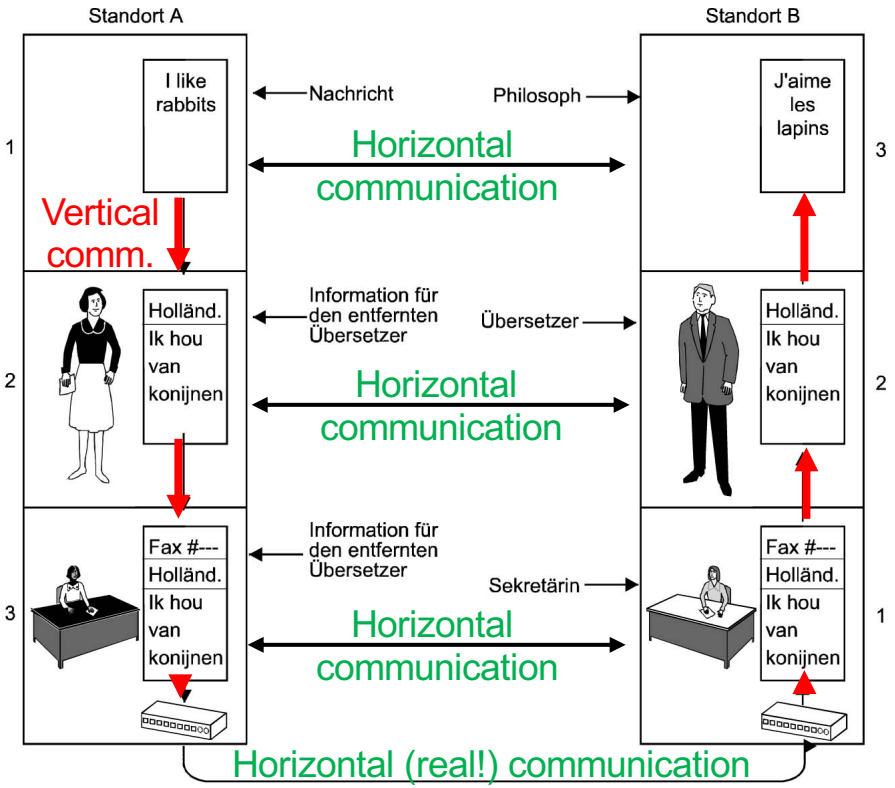
Assistants

Office clerks



Analogy: Nested Layers as nested Translations

- Vertical vs. horizontal communication
  - Vertical:
    always real
  - Horizontal:
    may be real or virtual
- Note: protocols interchangeable as long as the interface remains unchanged, e.g.:
  - Layer 2: Dutch => French
  - Layer 3: Fax => E-Mail

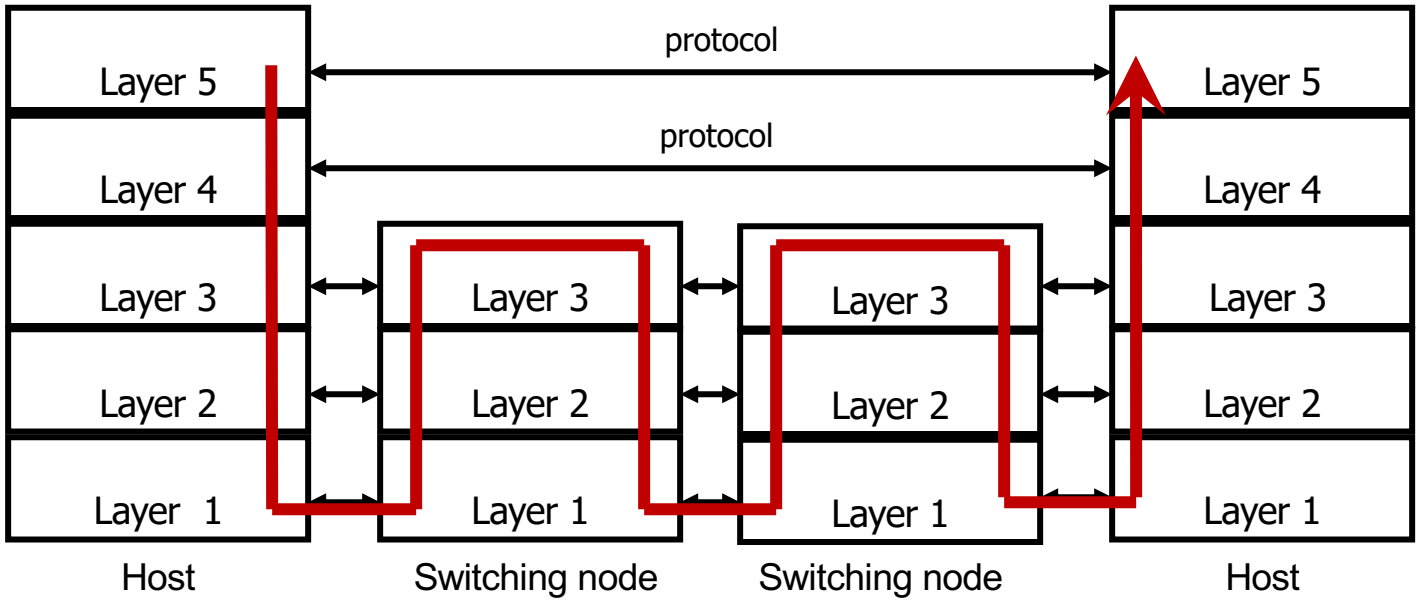


The Reference Model

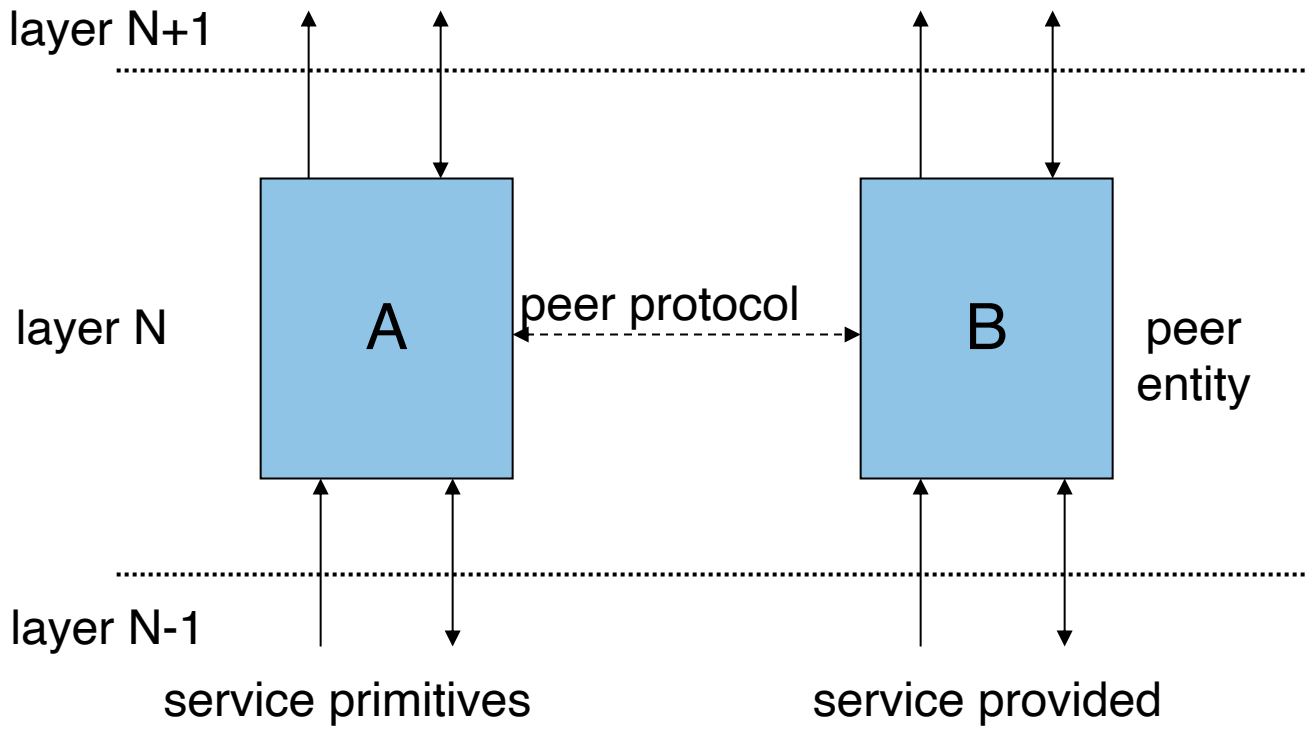
- To keep **complexity** of communication systems tractable:
  - Division in subsystems with clearly assigned responsibilities – layering
- Each layer offers a particular **service**
  - More abstract and more powerful the higher up in the layering hierarchy
- To provide a service, a layer has to be distributed over remote devices
- Remote parts of a layer use a **protocol** to cooperate
  - Make use of service of the underlying layer to exchange data
  - Protocol is a horizontal relationship, service a vertical relationship
- Layers/protocols are arranged as a (protocol) stack
  - One atop the other, only using services from directly beneath
  - **Strict layering** (alternative: cross-layering)

Multi-layer Architecture

- Number of Layers,
  {services, naming, and addressing conventions} / Layer
- Functions to be executed in each layer
- Protocols: (host-to-host, node-to-node, host-to-node)

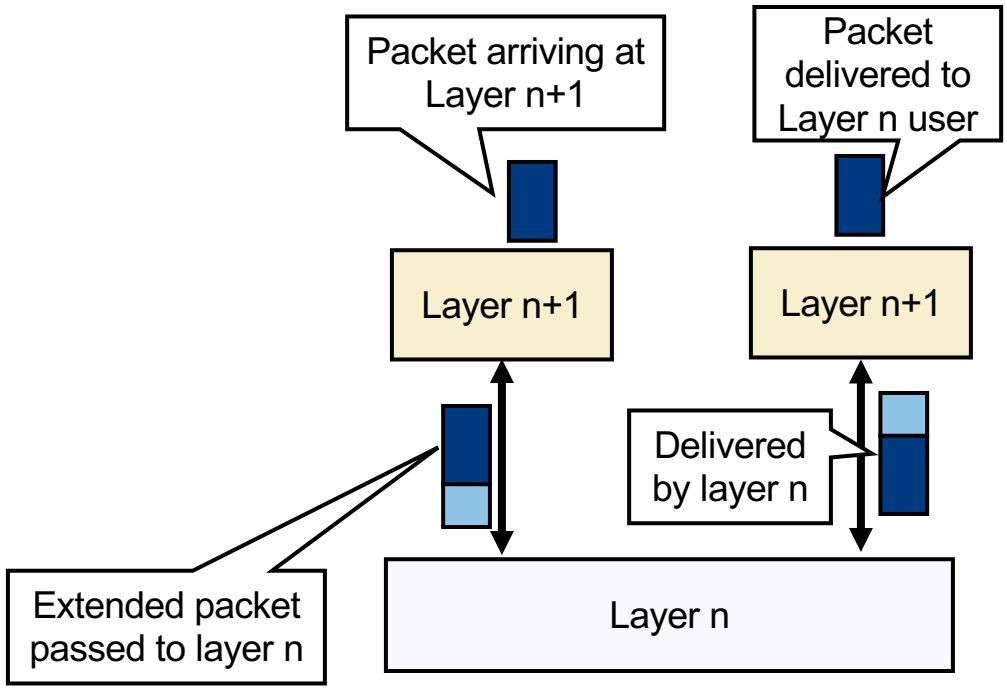


Multi-layer Architecture (II)



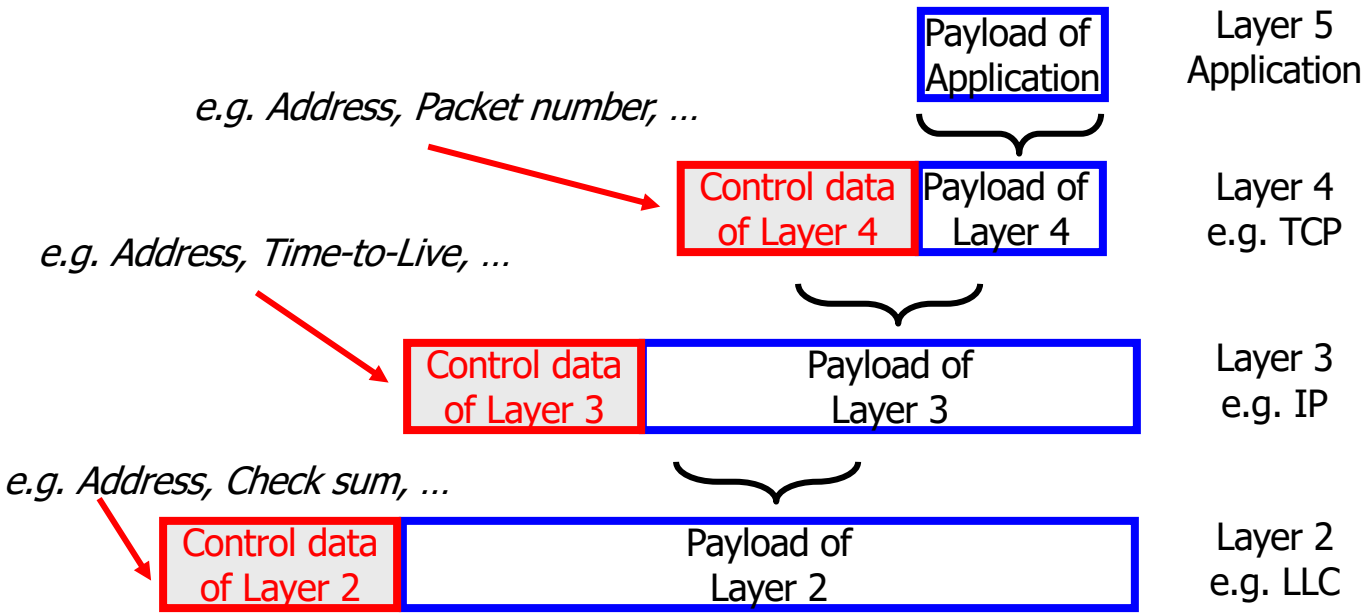
Protocols and Messages

- When using lower-layer services to communicate with the remote peer, administrative data is usually included in those messages
- Typical example
  1. Protocol receives data from higher layer,
  2. Adds own administrative data,
  3. Passes the extended message down to the lower layer,
  4. Receiver will receive original message plus administrative data.
- Encapsulating
  - Header or trailer



Embedding Messages

- Messages from upper layers are used as payload for messages in lower layers



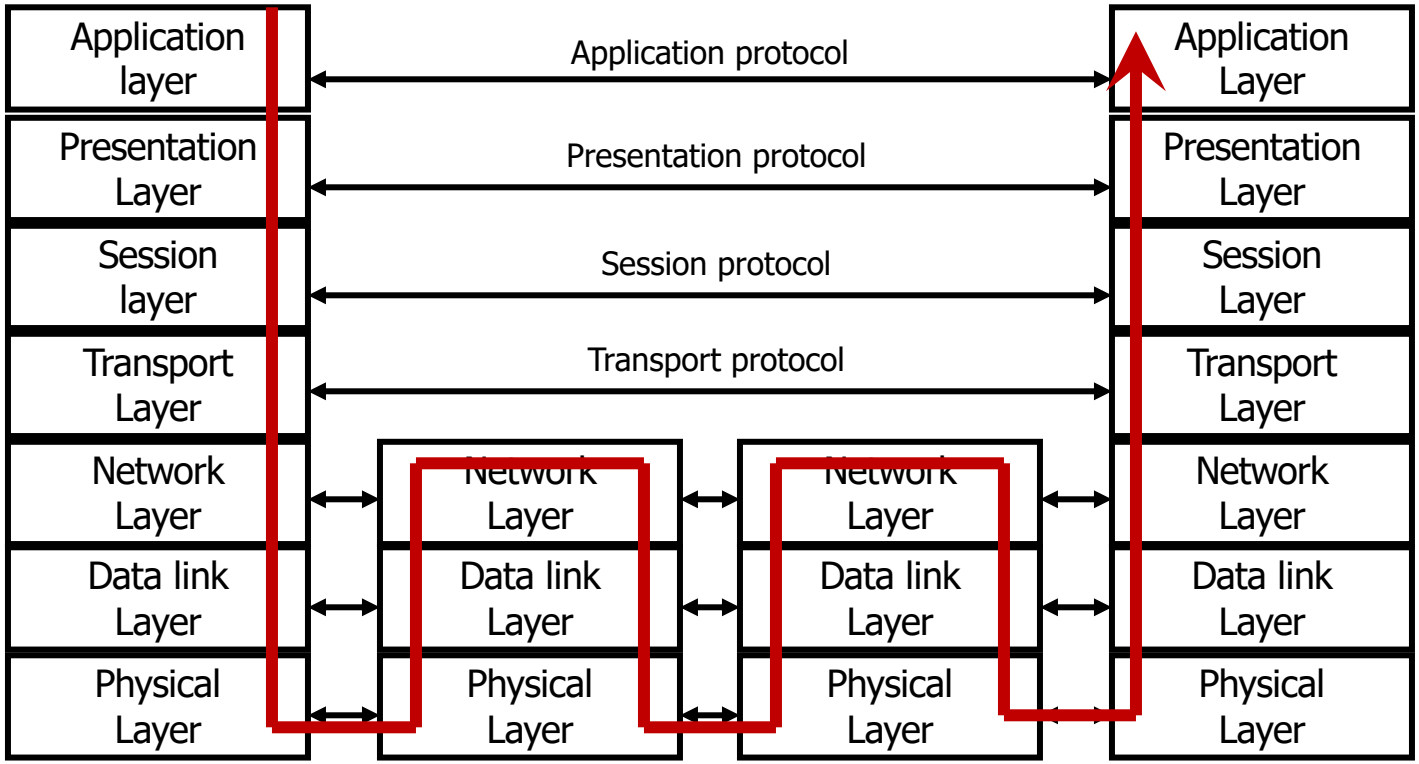
How to structure Functions/Layers?

- Many functions have to be realized
- Not each function is necessary in each layer
- How to actually assign them into layers to obtain a real, working communication system?
  - This is the role of a specific **reference model**
- Two main reference models exist
  - ISO/OSI reference model (International Standards Organization Open Systems Interconnection)
  - TCP/IP reference model (by IETF – Internet Engineering Taskforce)

ISO/OSI Reference Model

- Basic **design principles**
  - One layer per abstraction of the “set of duties”,
  - Choose layer boundaries such that information flow across the boundary is minimized (minimize inter-layer interaction),
  - Enough layers to keep separate things separate, few enough to keep architecture manageable.
- Result: **7-layer model**
  - Not strictly speaking an architecture, because
  - Precise interfaces are not specified (nor protocol details!)
  - Only general duties of each layer are defined

ISO/OSI Model



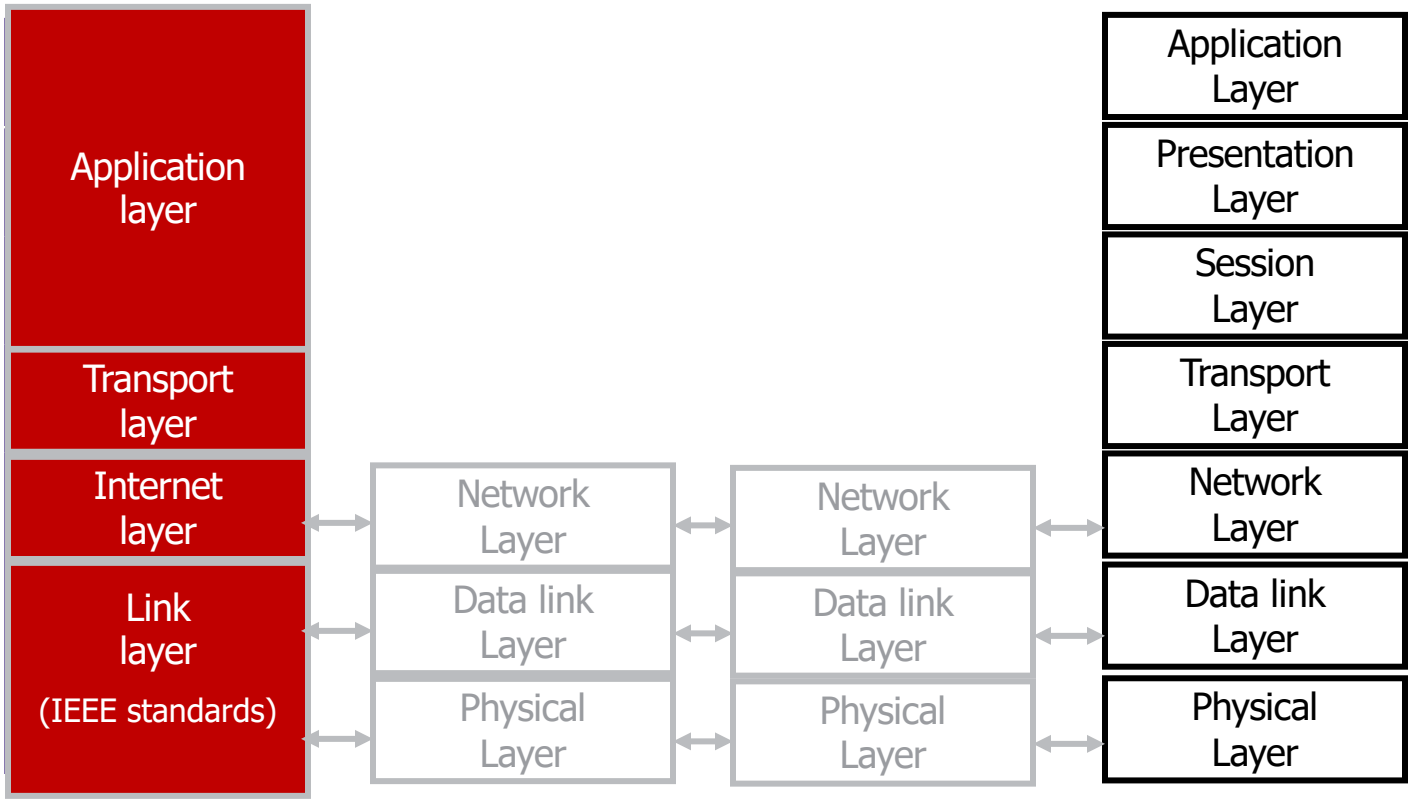
Brief Overview of the 7 Layers

- **Physical layer**: Transmit raw bits over a physical medium
- **Data Link layer**: Provide a (more or less) error-free transmission service for data frames - also over a shared medium!
- **Network layer**: Solve the forwarding and routing problem for a network - bring data to a desired host
- **Transport layer**: Provide (possibly reliable, in order) end-to-end communication, overload protection, fragmentation to processes

  "Bringing data from process A to B with sufficient quality"
- **Session layer**: Group communication into sessions which can be synchronized, checkpointed, …
- **Presentation layer**: Ensure that syntax and semantic of data is uniform between all types of terminals
- **Application layer**: Actual application, e.g., protocols to transport web pages

Internet Model (in red) vs. ISO/ OSI

- Presentation, session & physical layer not present in Internet model



Architecture, Protocols

- A communication architectures needs **standard protocols** in addition to a layering structure
- And some **generic rules & principles** which are not really a protocol but needed nonetheless
  - Example principle: **end-to-end**
  - Example rule: naming & addressing scheme
- Popular protocols of the Internet reference model
  - Data link layer: Ethernet & CSMA/CD (defined in IEEE standard)
  - Network layer: Internet Protocol (IP)
  - Transport layer: Transmission Control Protocol (TCP)

Internet Reference Model

- Historically based on ARPANET, evolving to the Internet
  - Started out as little university networks, which had to be interconnected
- Some generic rules & principles
  - Internet connects **networks**
    - Minimum functionality assumed (just unreliable packet delivery)
    - Internet layer (IP): packet switching, addressing, routing & forwarding

    → **Internet over everything**
  - End-to-end
    - Any functionality should be pushed to the instance needing it
  - Fate sharing
- In effect only two layers really defined: Internet and Transport Layer - lower and higher layers not really defined

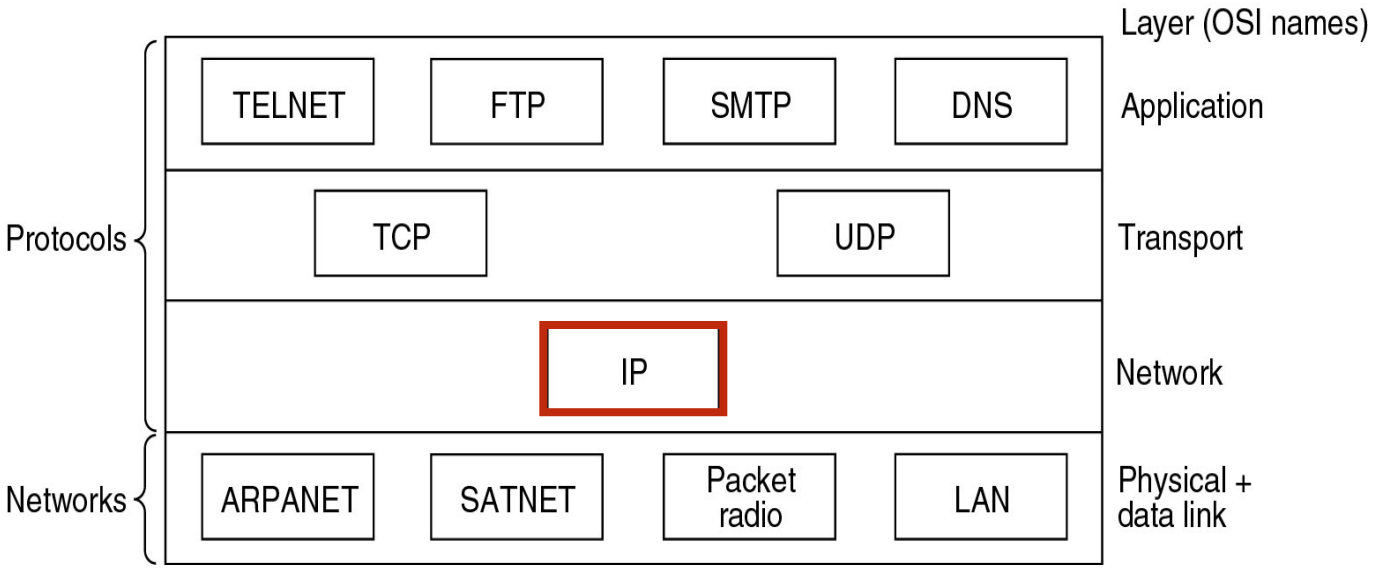
  → **Anything over Internet**
- New applications do not need any changes in the network
  - Compare with the telephone network

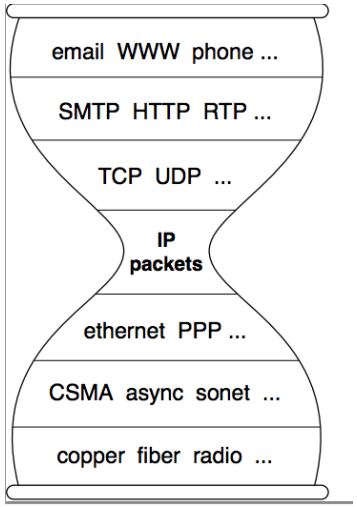
The Internet Suite of Protocols

- Over time, suite of protocols evolved around core TCP/IP protocols

→ Internet Protocol Suite is also refereed to as TCP/IP Protocol Suite

→ "**hourglass model**": thin waist of the protocol stack at IP, above technological layers





Naming & Addressing in the Internet Stack

- **Names**: Data to **identify** an entity exist on different levels
  - Alphanumerical names for resources: e.g. saturn.tkn.tu-berlin.de, www.tkn.tu-berlin.de
- **Address**: Data how/where to **find** an entity
  1. Address of a network device in an IP network: an IP address
     - IPv4: 32 bits, structured into 4x8 bits
     - Example: 131.234.20.99 (dotted decimal notation)
  2. Address of a network: Some of the initial bits of an IP address
- Address of a networked device in the Local Area (IEEE 802 standardized) Network (LAN): a MAC address
  - 48 bits, hexadecimal notation, example: 08:00:20:ae:fd:7e

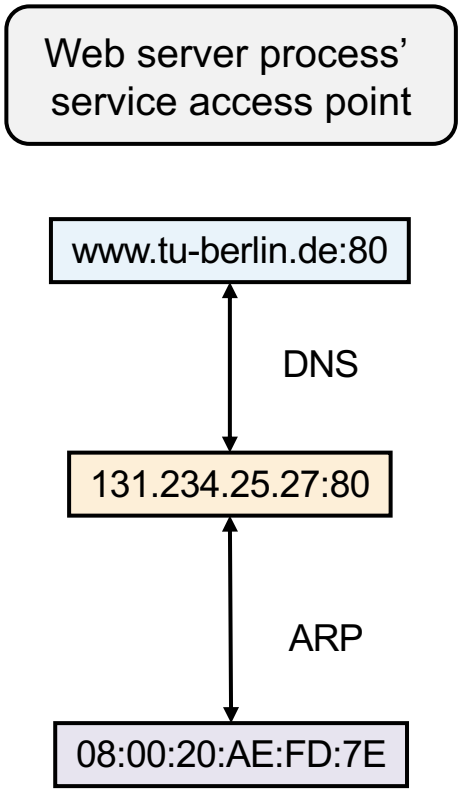
Mapping

- Needed: mapping from name to address

→ realized by separate protocols

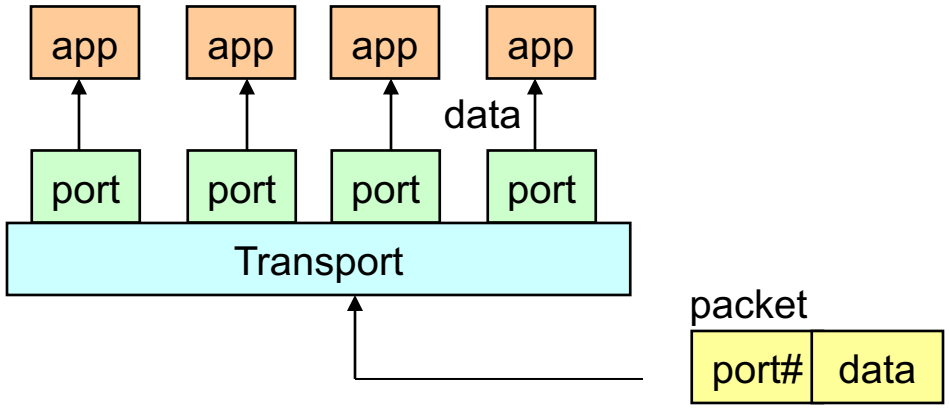
- From alphanumerical name to IP address: **Domain Name System** (DNS)

- Often also needed: mapping from IP address to MAC address: **Address Resolution Protocol** (ARP)



Understanding Ports

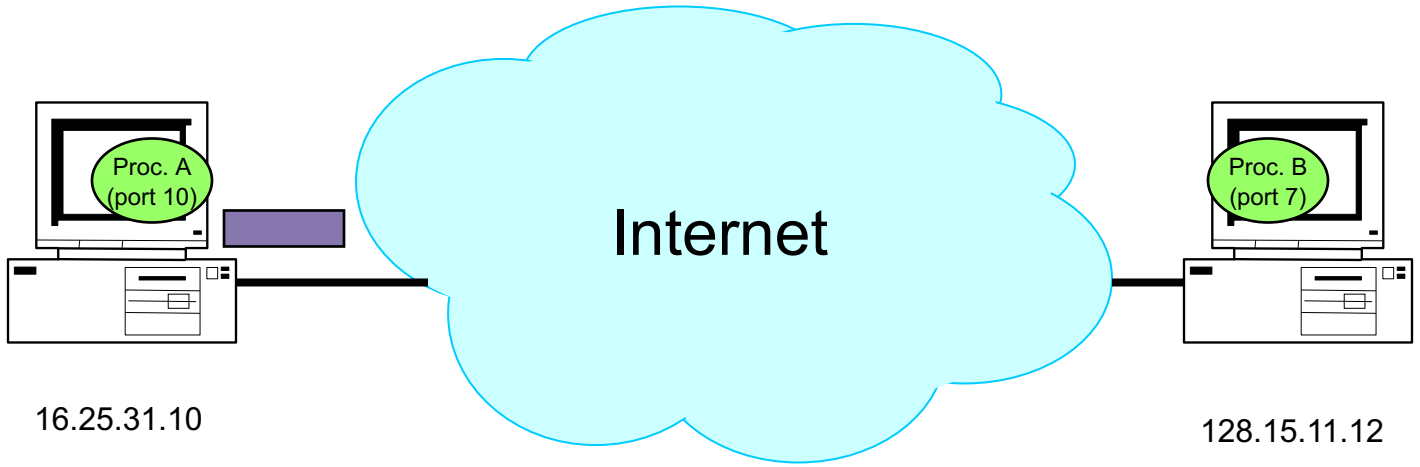
- … to distinguish between individual processes
- Port is represented by a positive (16-bit) integer value
- Some ports have been reserved to support common/well known services: http 80/tcp; ftp 21/tcp; telnet 23/tcp; smtp 25/tcp;
- User level process/services generally use port number value >= 1024



[Buya, op. cit.]

Internet End-to-End View

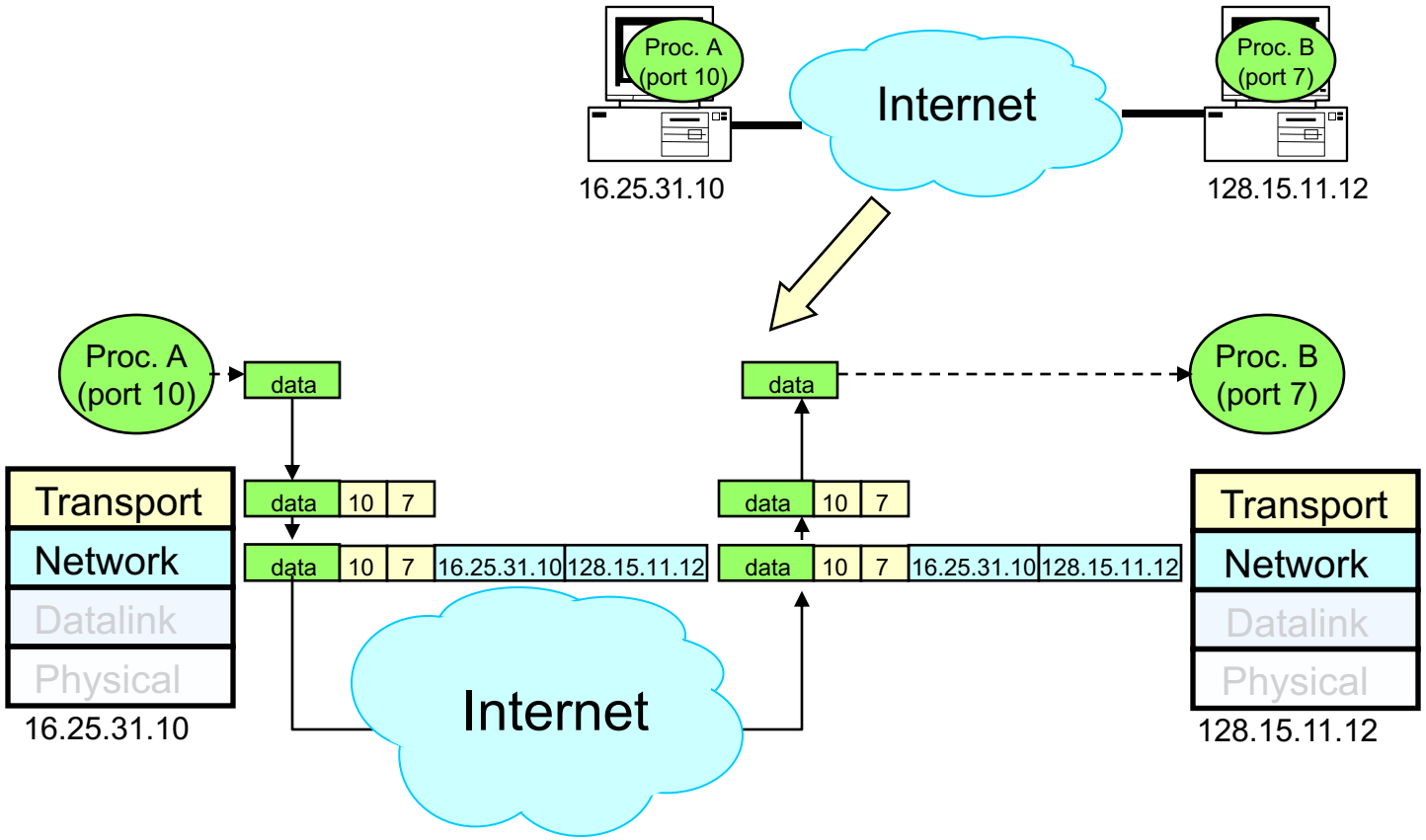
- Process A sends a packet to process B



IP address:
A four-part "number" used by Network Layer to route a packet from one computer to another

[Stoica, op. cit.]

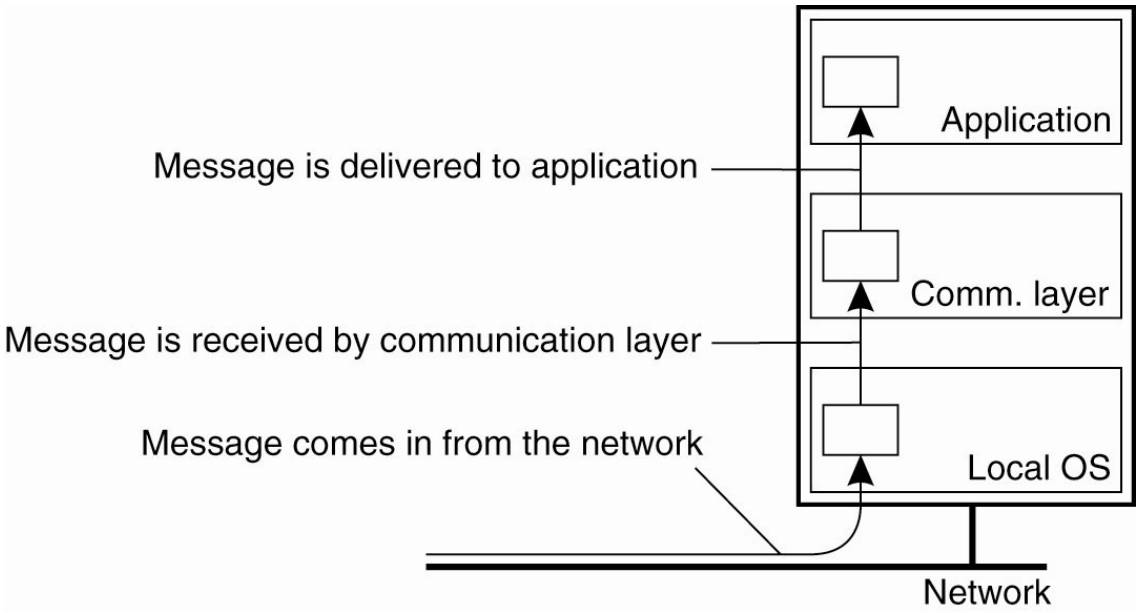
End-to-End Layering View



[Stoica, op. cit.]

Message Receipt vs. Message Delivery

- The logical organization of a distributed system to distinguish between message receipt and message delivery.

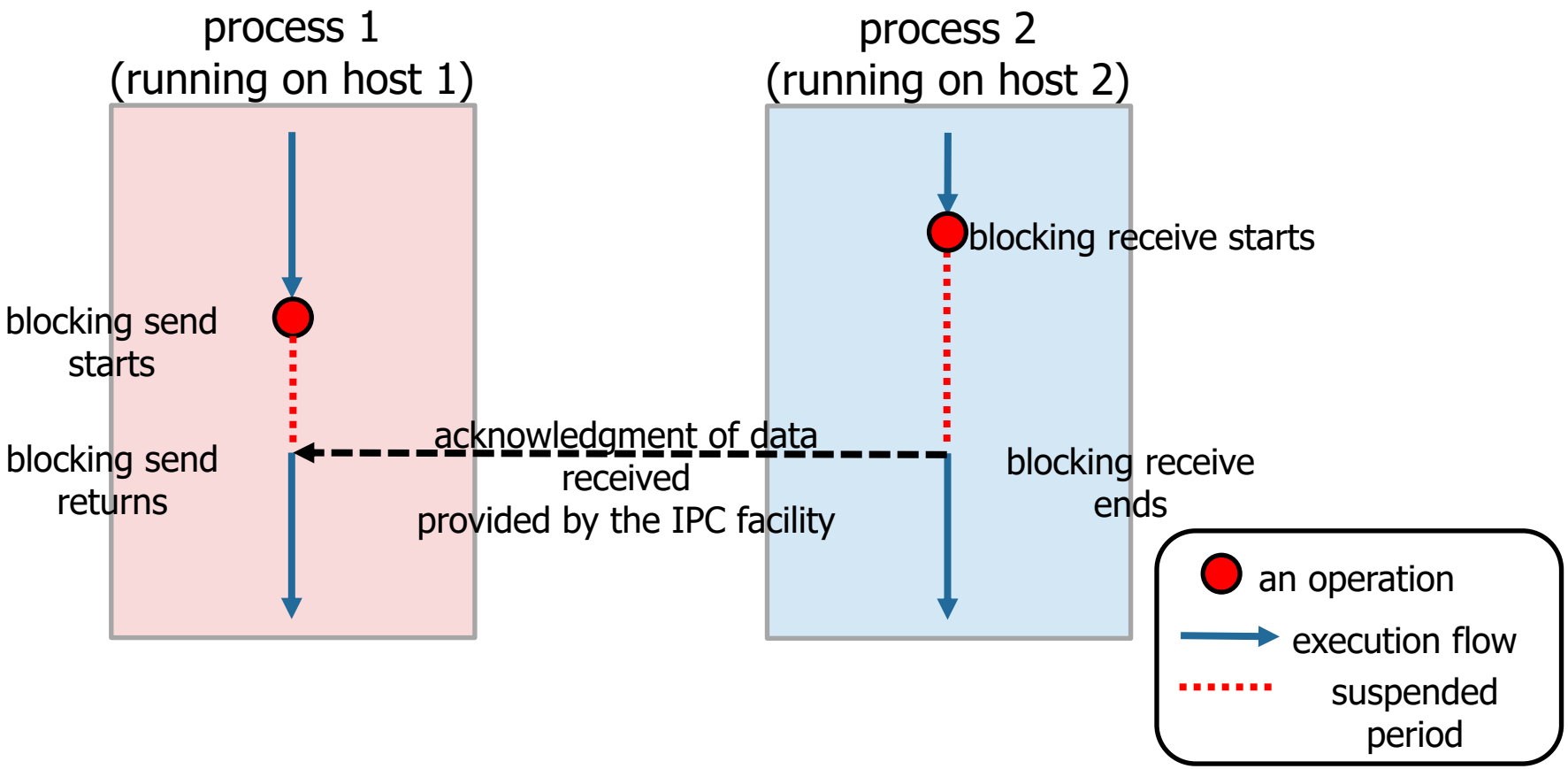


Interaction Principles: Synchronous Interaction

- Blocking send
  - Blocks until message is transmitted
  - Blocks until message acknowledged
- Blocking receive
  - Waits for message to be received

- **You should know**: upper/lower bounds on execution speeds, message transmission delays and clock drift rates

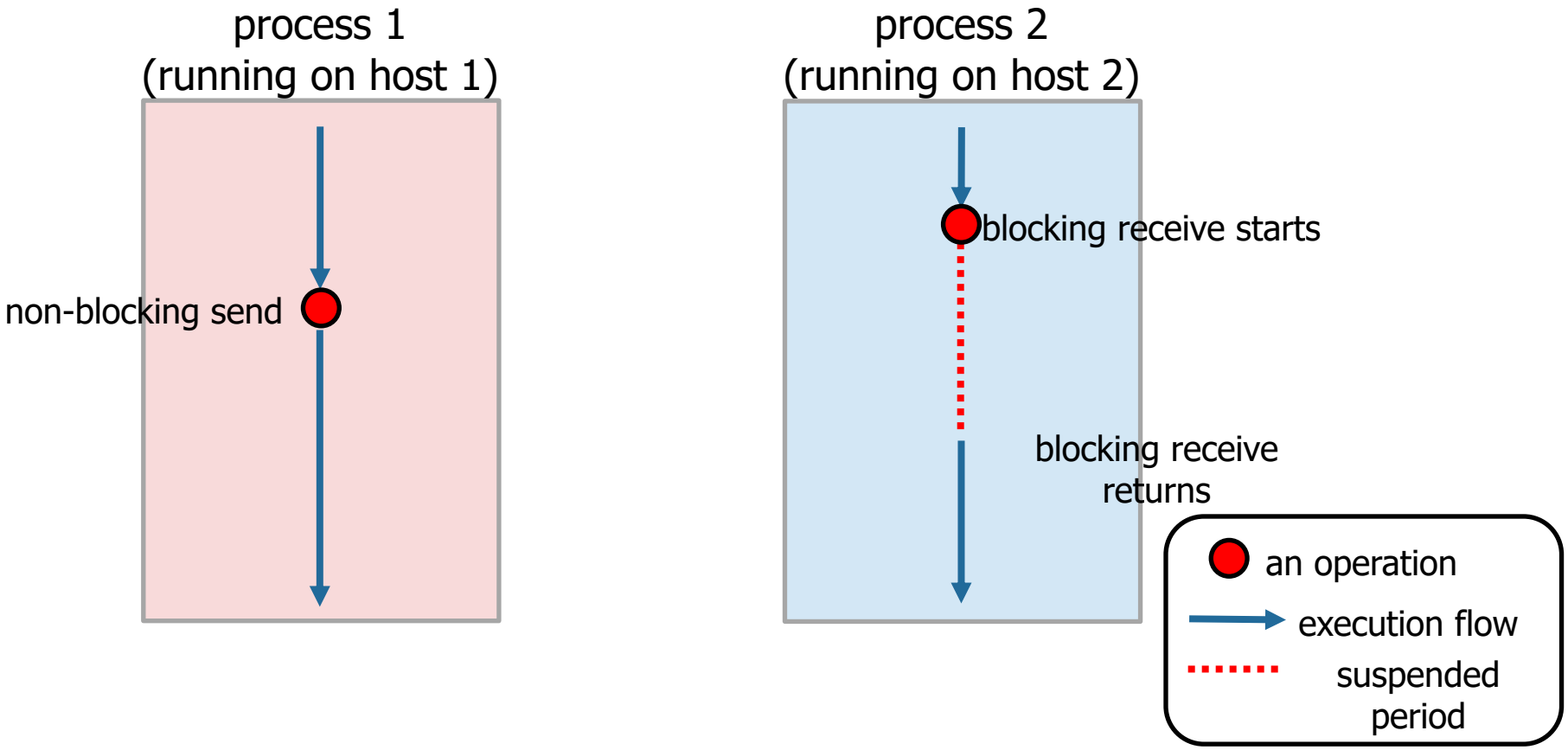
Synchronous Send & Receive



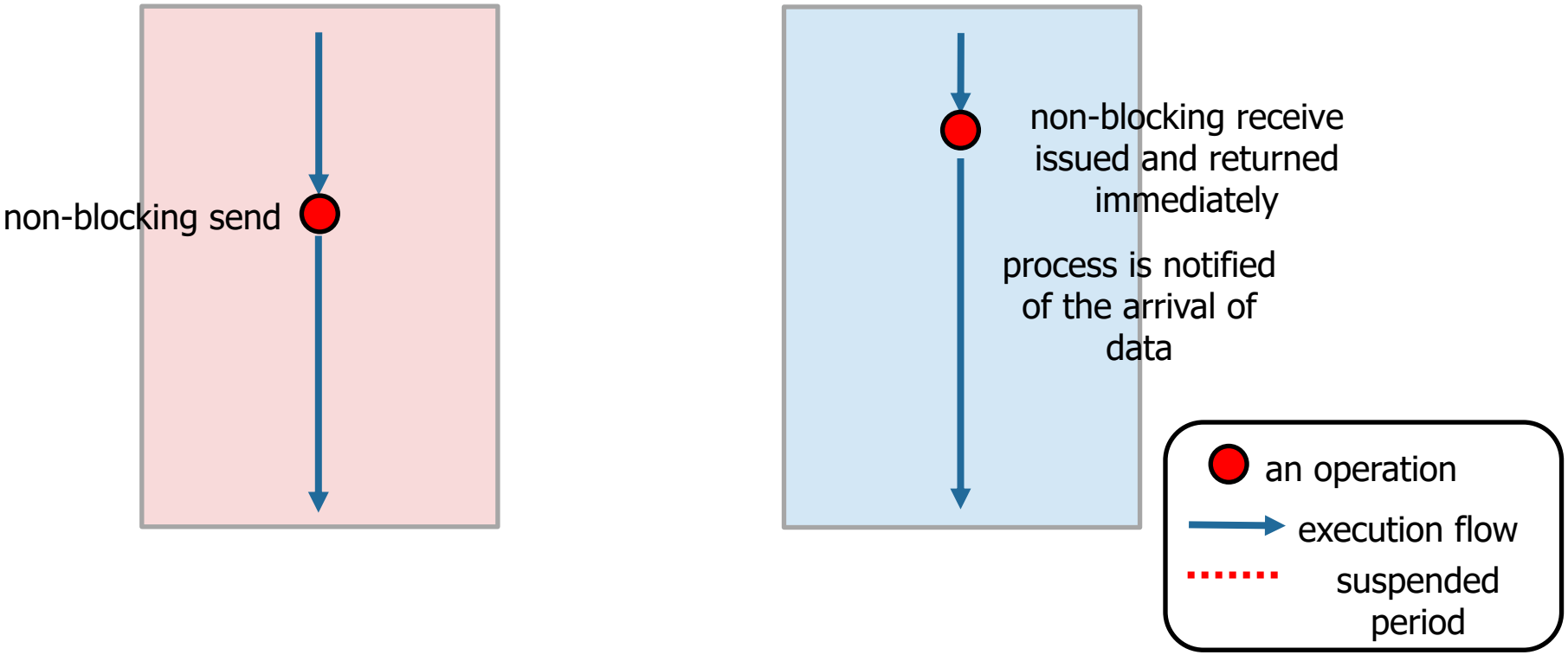
Interaction Principles: Asynchronous Interaction

- Non-blocking send: sending process continues as soon message is **queued**
- Blocking or non-blocking receive:
  - Blocking:
    - Timeout
    - Threads
  - Non-blocking: proceeds while waiting for message
    - Message is queued upon arrival
    - Process needs to poll or be interrupted
- **Advantage**: arbitrary process execution speeds, message transmission delays and clock drift rates
- Some problems impossible to solve (e.g., agreement)

Asynchronous Send & Synchronous Receive



Asynchronous Send & Asynchronous Receive



Standardisierung

Standardisierung

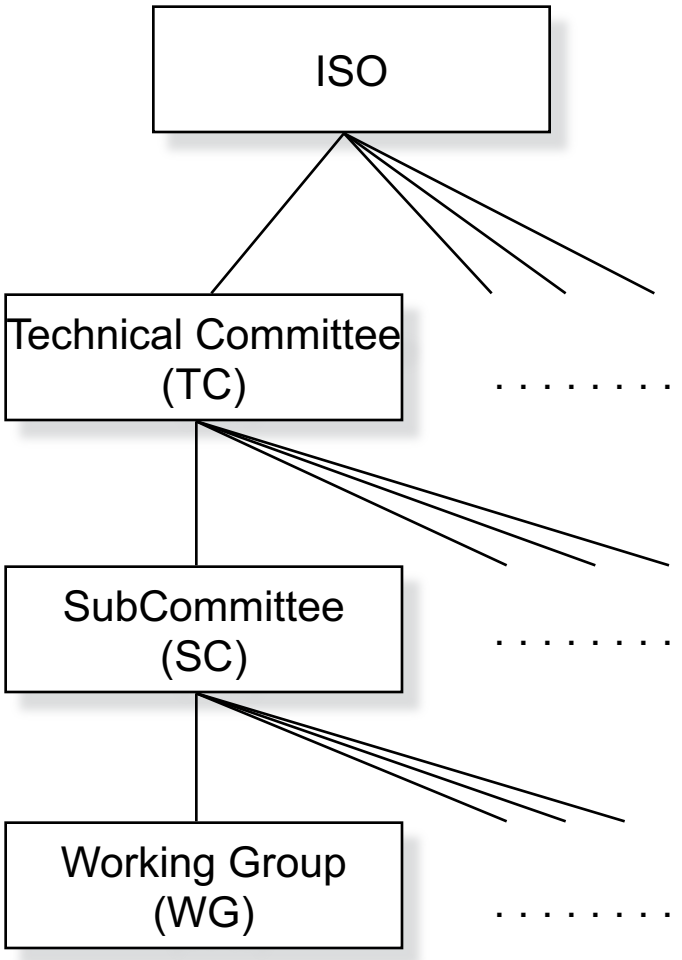
- Essentiell, um große, weltumspannende Netze zu realisieren
- Traditionell durch Organisationen getrieben mit Hintergrund in Telekommunikation / Telefonie
  - Etabliert, weltweit, relativ langsame “time to market”
- Internet
  - Im Wesentlichen durch Internet Engineering Task Force (IETF) mit assoziierten Organisationen (Internet Architectural Board IAB, Internet Research Task Force IRTF, Internet Engineering Steering Group IESG)
  - Consensus-orientiert, starker Fokus aus funktionierenden Implementierungen
  - Initial schnelle “time to market”, heute aber auch deutlich langsamer
- Hersteller mit ihren jeweiligen Interessen
  - „de facto“-Standards

Standardisierung – Traditionelle Organisationen

- ITU – International Telecommunication Union (formerly CCITT und CCIR)
- CCITT – Consultative Committee on International Telegraphy and Telephony (Comité Consultatif International Télégraphique et Téléphonique)
- CCIR – Consultative Committee on International Radio
- CEPT – Conférence Européenne des Administrations des Postes et des Télécommunications
- ISO – International Organization for Standardization
- DIN – Deutsches Institut für Normung
  - German partner organization of ISO

ISO-Standardisierung

- WG-Treffen:
  - Alle 6-9 Monate
  - Nationale Organisationen haben Zeit, um vorgeschlagene (proposed) Konzepte zu akzeptieren
  - Dann: der eigentliche Standardisierungsprozess
    - DP: Draft Proposal
    - DIS: Draft International Standard
    - IS: International Standard
- Standard ist mehr eine Empfehlung für übergeordnete Gremien durch internationalen Konsens
- Sehr langsamer Prozess



IETF

- IETF ist organisiert in Areas und Arbeitsgruppen (Working Groups)
  - Vertreter von Industrie, Universitäten und Regierungen
- Drafts/Proposal kann von jedem eingebracht werden
  - „on-demand“
- Für Standardisierung werden mindestens zwei unabhängige Implementierungen benötigt
- Informelles Abstimmen (Voting) in Arbeitsgruppen
  - „Humming“
  - Drei Treffen pro Jahr
- Ergebnis:
  - RFC – request for comment, der eigentliche Standard
  - FYI – informal bzw. informational
- Januar 2019: 8521 RFCs
  - So funktioniert das Internet