Introduction

Common Examples of Communications Networks

- The desktop computer and the Internet
- A laptop computer and a wireless connection
- Cell phone networks
- Industrial sensor-based systems
- Mainframe systems
- Satellite and microwave networks

Motivation

- **INTERNET**
- Exponential growth of traffic
- Development of new applications and services
- Advances in technology

- Application requirements drive technology (or vice-versa?)

Motivation (contd)

- What's there to understand about communication/computer networks?
  - Applications, Protocols, Networking architecture
  - Links, Switches, Middleboxes
- Terms used often
  - Bandwidth, Latency, Performance, Quality of Service, User Experience
- Links: Wired, Wireless
- Bandwidth: 56kbps to 100Gbps
  - Is it only medium of transmission or something beyond?

Application Requirements

- Traditional vs Multimedia applications
- Client-server vs Peer-to-peer applications
- Elastic vs Inelastic Traffic
- Adaptive vs non-adaptive applications

- Performance of network/communication system meets requirements
  - Throughput/Data rate
  - Latency
  - Other qualitative and quantitative requirements

Data Communication

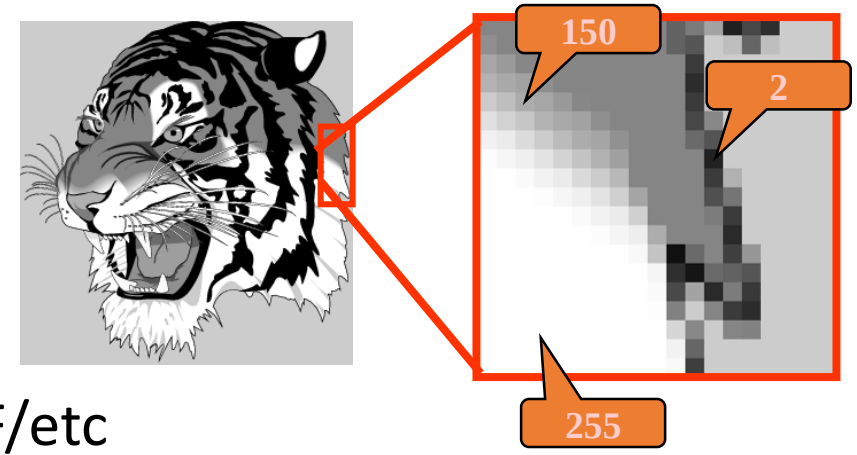
- Deals with sending **information reliably** from one place to another while conforming to the **user requirements**

- The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point

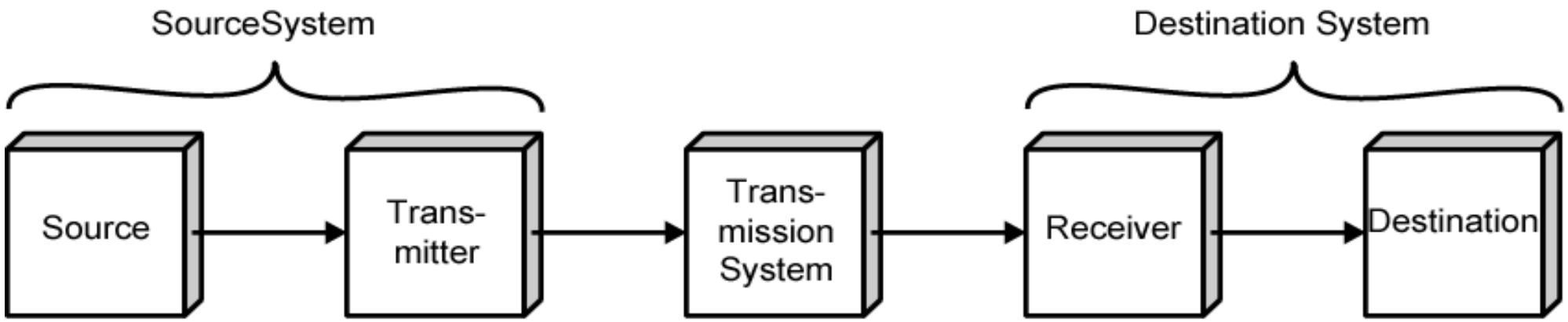
  - The Mathematical Theory of Communication, Claude Shannon

Data Representation

- Numbers
  - 8/16/32 bit integers
  - floating point
- Text
  - ASCII, Unicode
- Images
  - Bit patterns, Graphics formats JPG/GIF/etc
- Audio → Samples of continuous signal
- Video → Sequence of bitmap images



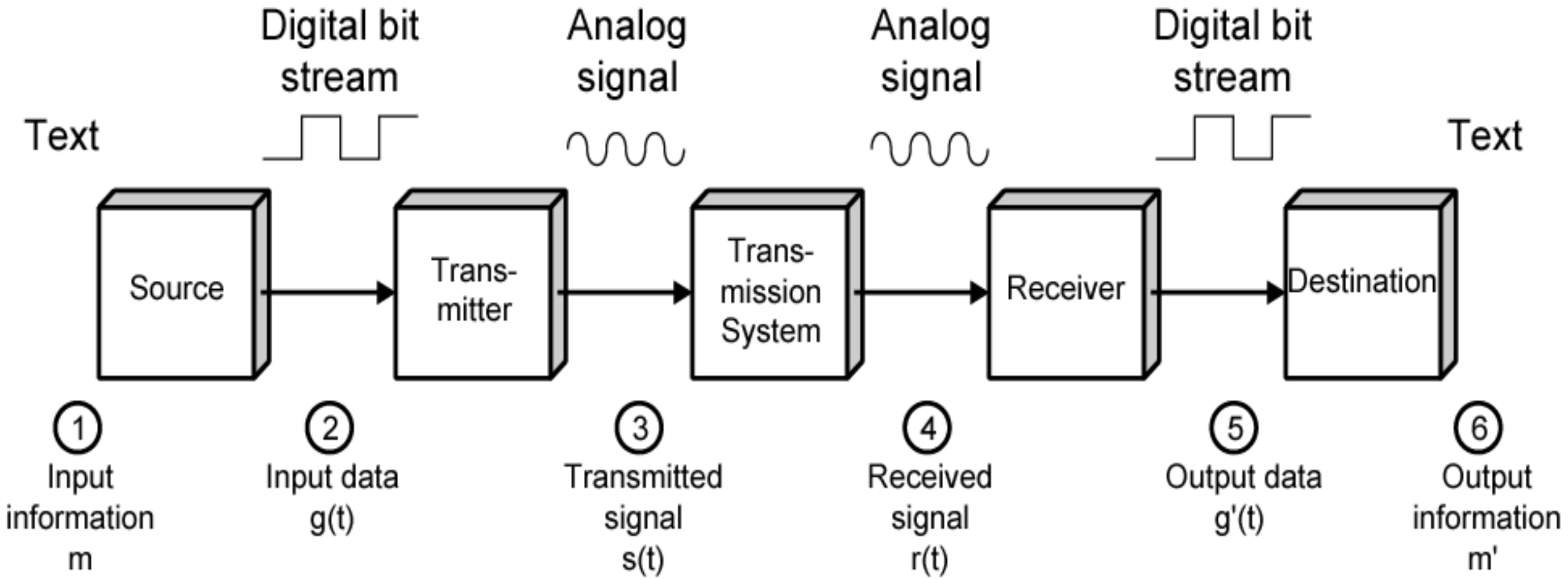
Communication Model



(a) General block diagram

(b) Example

Communication Model (contd)



Communication Tasks

- Signal generation and recovery
- Interfacing
- Synchronization
- Error detection and correction
- Addressing
- Routing
- Message formatting
- Flow control
- Congestion Control
- Session management
- Network management
- Security

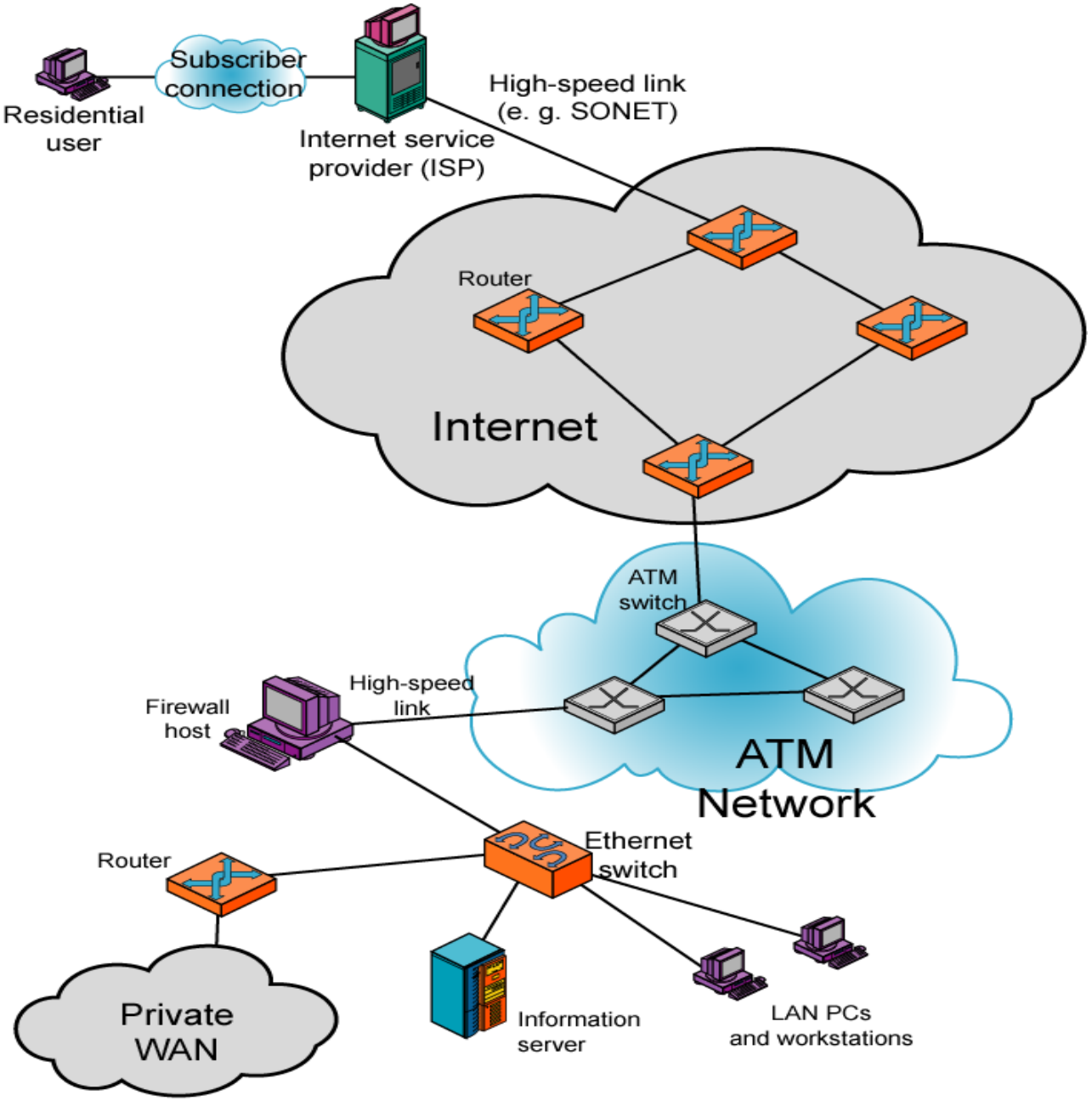
Transmission Medium

- Twisted pair, coaxial cable,fiber-optic, wireless, infrared
- Choice of medium
  - Distance vs cost, (short-range or trans-pacific)
- Heterogeneity in links, data requirements
  - Rapid advancement in technology
- High transmission costs → Efficient utilization

Networks

- Growth of number & power of devices - interconnection needs
- Rapid growth in integrated applications (voice, text, video)
- Scalability and Efficiency
  - Point-to-point, multipoint communication
  - Better resource utilization
- Build networks according to requirements
  - Local area networks (LAN)
  - Metropolitan area networks (MAN)
  - Wide area networks (WAN)

Typical Configuration



Local Area Networks

- Shorter Reach
  - Building or small campus
- Usually owned and operated by same organization
- Data rates per user much higher (lower sharing level)
- Switched LANs, e.g. Ethernet
- Wireless LANs
  - Easy mobility
  - Easier to install
- Popularly broadcast or shared medium-based networks

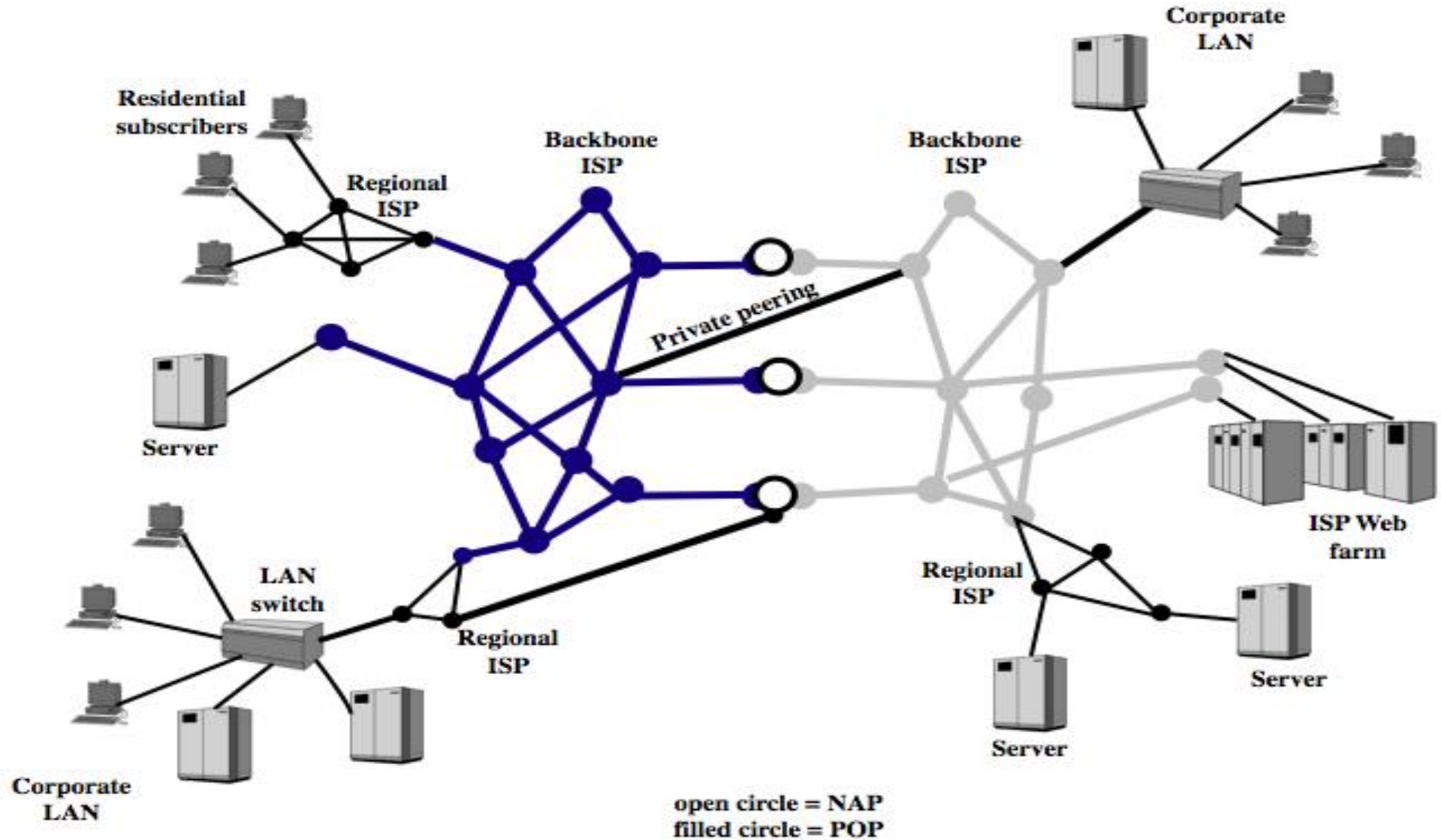
Wide Area Networks

- Larger geographical reach: country or continents
- Crossing several administrative and political domains
- Operated and owned by different parties
- Rely on common carrier circuits
- Several Technologies
  - Circuit Switching (Wavelength division multiplexing (WDM) optical)
  - Packet Switching (IP or Frame Relay)
  - Asynchronous Transfer Mode (ATM)
  - Multiprotocol Label Switching

Internet

- Evolved from ARPANET (1969), first packet switched network
- Highly inter-operable (heterogeneous links, networks,protocols)
- Standardised through TCP/IP architecture and suite of protocols
- Reasons
  - End-to-end argument
  - Layering and Modularity
  - Best-effort packet delivery model
  - Increased public usage and contribution to development (WWW)
  - Killer applications every decade

Internet Structure



Network Architecture: What's in a network?

- Hardware:
  - Hosts (PC, Laptop, Mobile, Other devices)
  - Switches (Gateway, Router, Middleboxes)
  - Links
- Software:
  - Layers and Protocols
  - Standards for inter-operability of protocols
- TCP/IP Architecture

OSI Layers

- Physical: how to transmit bits
- Data link: how to transmit frames
- Network: how to route packets
- Transport: how to send packets end2end
- Session: how to tie flows together
- Presentation: byte ordering, security
- Application: everything else

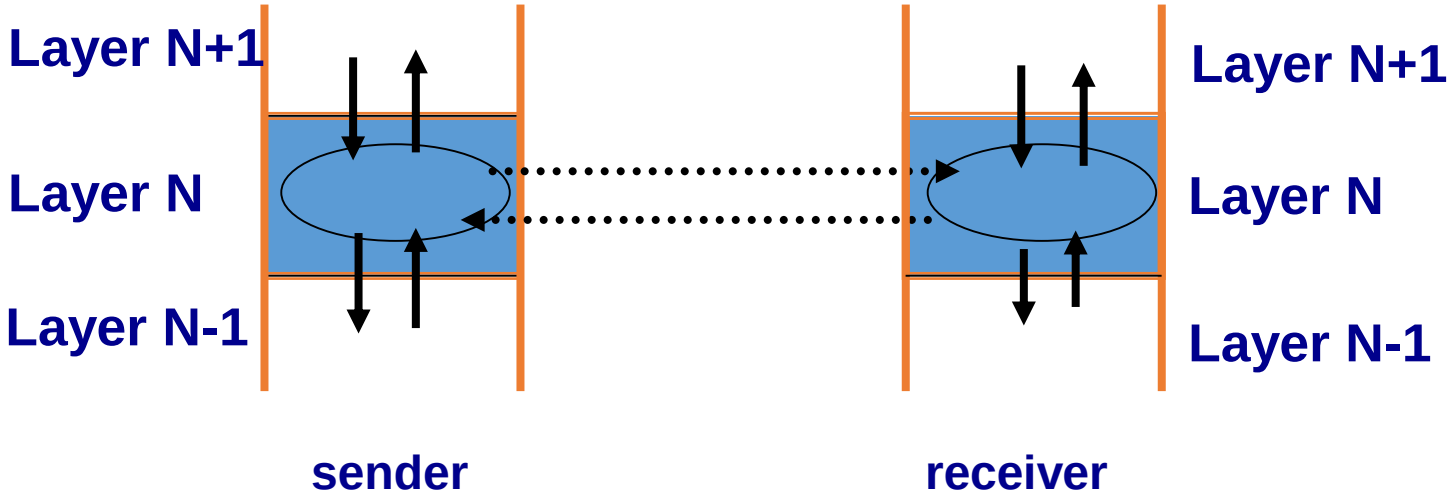
TCP/IP has been amazingly successful, and it's not based on a rigid OSI model. The OSI model has been very successful at shaping thought

Comparison of Network Models

OSI Model	Internet Model	Groups of Layers
7. Application Layer	5. Application Layer	***Application Layer***
6. Presentation Layer		
5. Session Layer		
4. Transport Layer	4. Transport Layer	***Internetwork Layer***
3. Network Layer	3. Network Layer	
2. Data Link Layer	2. Data Link Layer	***Hardware Layer***
1. Physical Layer	1. Physical Layer	

Protocols

- Used by Network model layers
- Sets of rules to define how to communicate at each layer and how to interface with adjacent layers



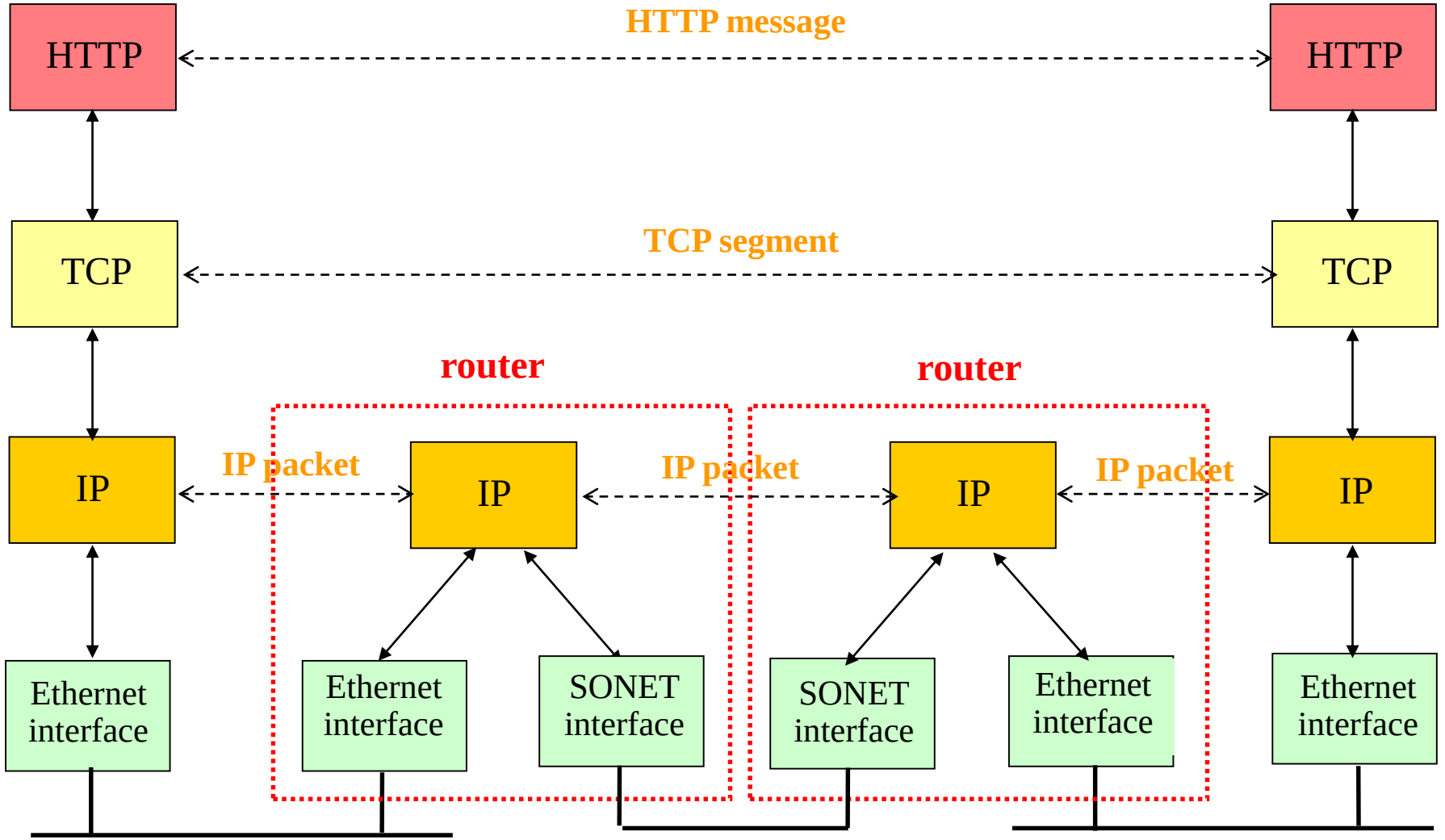
Protocols

- Module in a layered architecture
- A set of rules governing data communications
  - **Syntax:** format of data block
  - **Semantics:** meaning of each section
  - **Timing:** speed and sequencing
- Define interface to higher layers (API)
- Define interface to peer layers (syntax and semantics)
  - Format and order of messages
  - Action on receipt of messages
- Defined in standards and RFCs (ITU-T, IEEE, ISO)

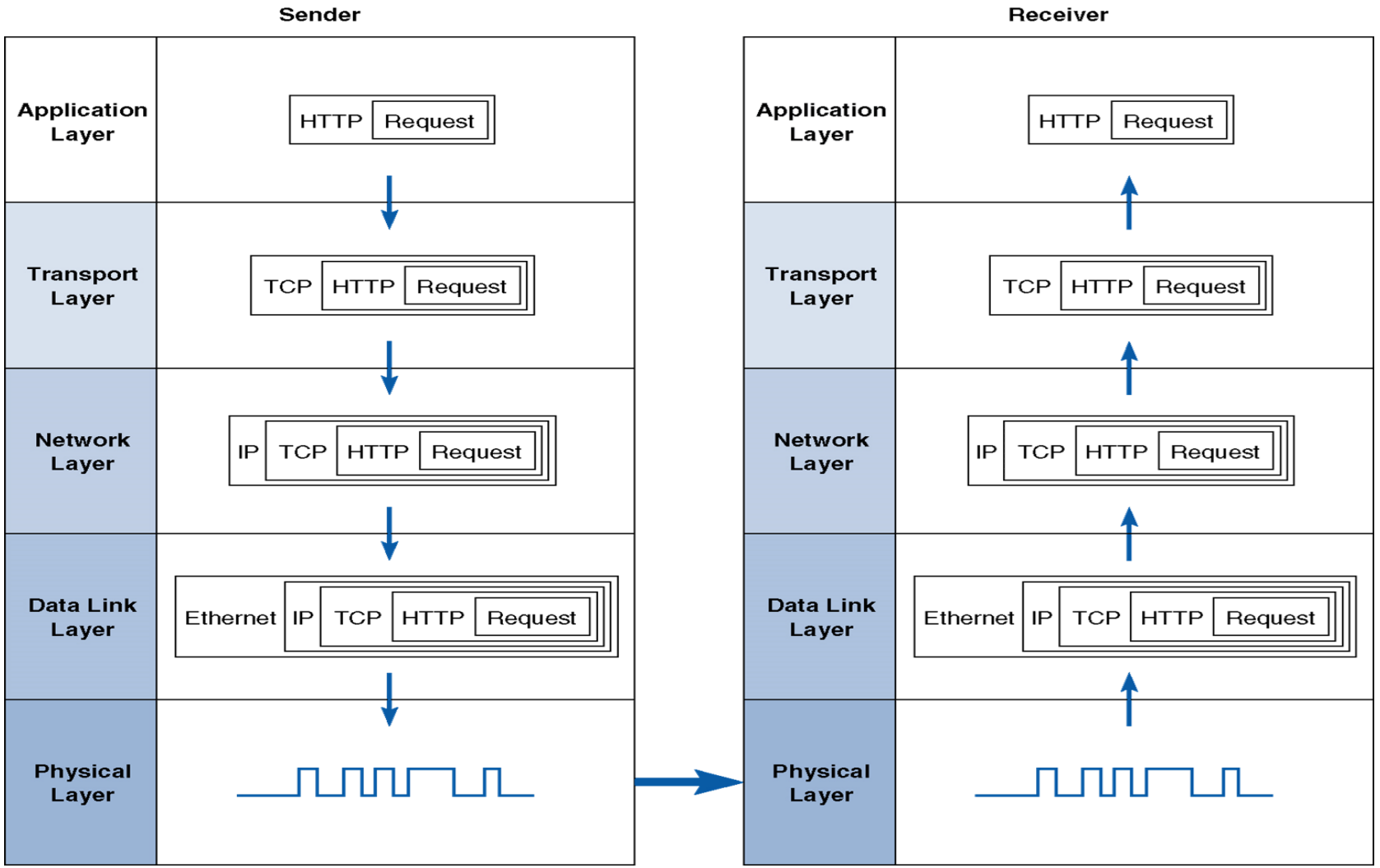
Some Data Comm. Standards

Layer	Common Standards
5. Application layer	HTTP, HTML (Web) MPEG, H.323 (audio/video) IMAP, POP (e-mail)
4. Transport layer	TCP (Internet) SPX (Novell LANs)
3. Network layer	IP (Internet) IPX (Novell LANs)
2. Data link layer	Ethernet (LAN) Frame Relay (WAN) PPP (dial-up via modem for MAN)
1. Physical layer	RS-232c cable (LAN) Category 5 twisted pair (LAN) V.92 (56 kbps modem)

Example with HTTP



Message Transmission Example



Layering: Pros and Cons

- Many different software packages (protocols) and many different packets (at different layers)
  - Easy to develop new software
  - Simple to change the software at any level
- Matching layers communicate at different computers
  - Accomplished by standards
  - e.g., Physical layer at the sending computer must be the same in the receiving computer
- Somewhat inefficient
  - Involves many software and packets
  - Packet overhead (slower transmission, processing time)