Appendix 0
Elements of Internet
附录0
互联网基础

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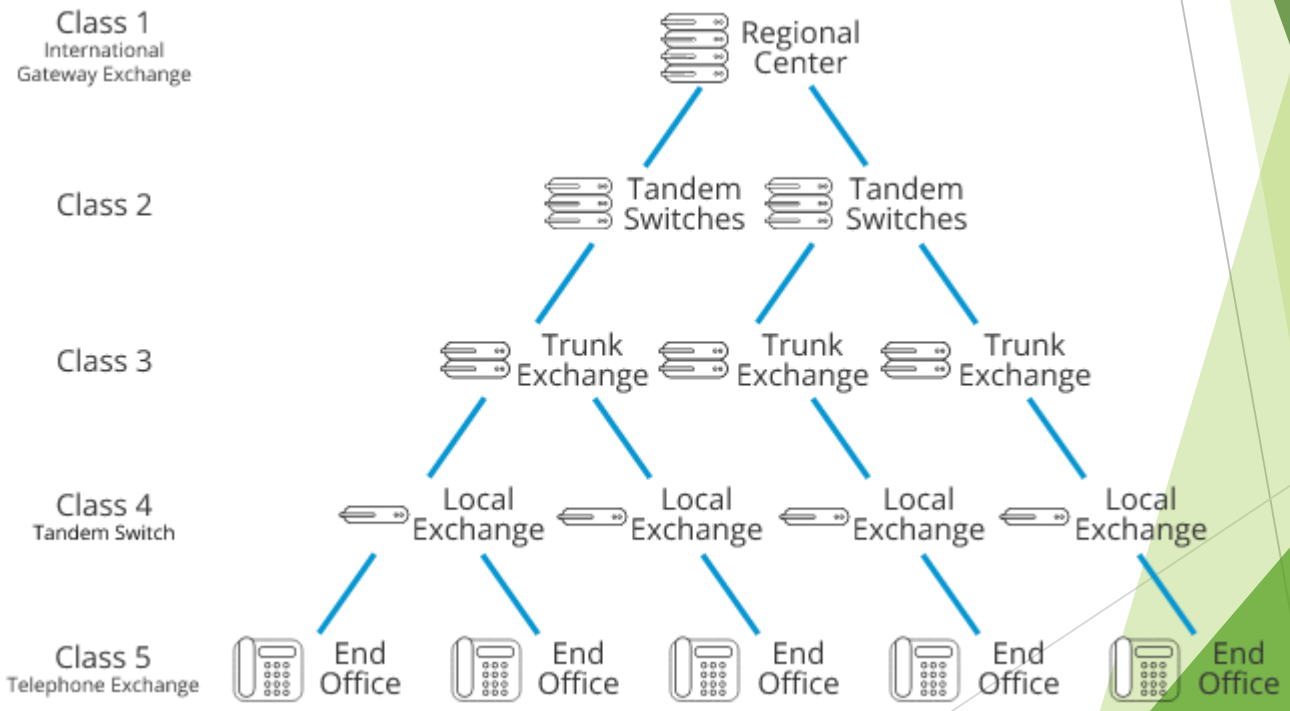
公共交换电话网 PSTN

- 在讲物联网之前，我们有必要来了解一下互联网的基本知识。为对互联网的特点有更好地了解，我们先看一下公共交换电话网，其如右图所示：

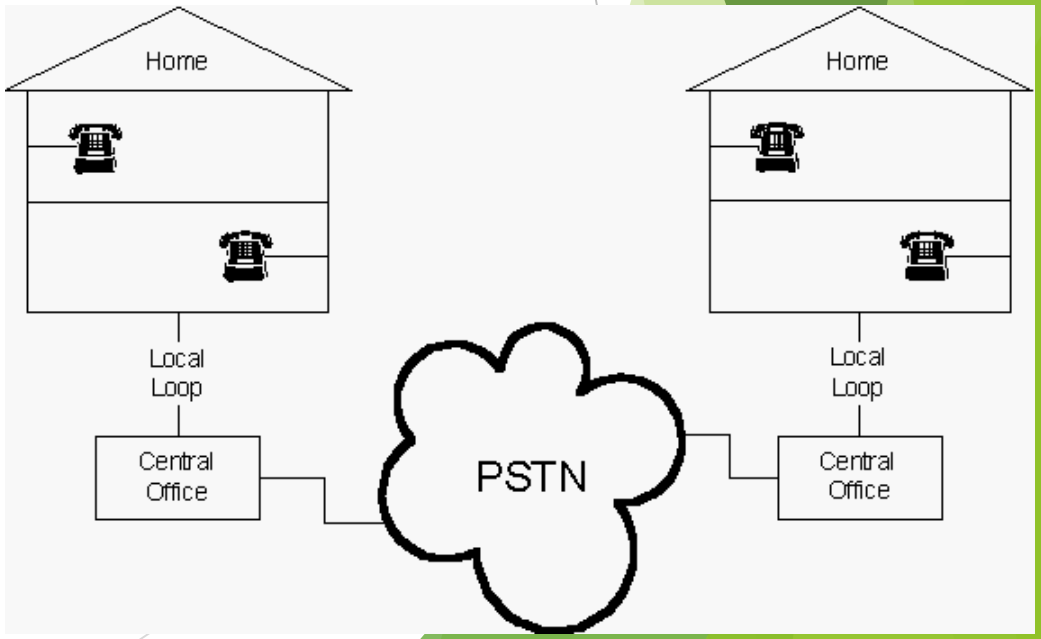
  It is necessary to recap the elements of Internet before we move into Internet of Things. However, for a better understanding of the characteristics of Internet, let's check the Public Switched Telephone Network (PSTN) first, shown as in the right figure:



公共交换电话网
PSTN

- 作为电路交换网络，PSTN中的呼叫者与被呼叫者在实际通话之前，会建立专用的电路。该过程又称资源预留，且建立的路径在整个通话过程中保持不变。尽管使用了分层的网络结构，PSTN的路由决策是集中化的，每个交换机只能访问有限的替代路径。因为PSTN无法实时地通过间接的物理链路来重新搜索替代路径，如果最直接的路径不可用或所有中继线路忙碌，呼叫可能无法继续。

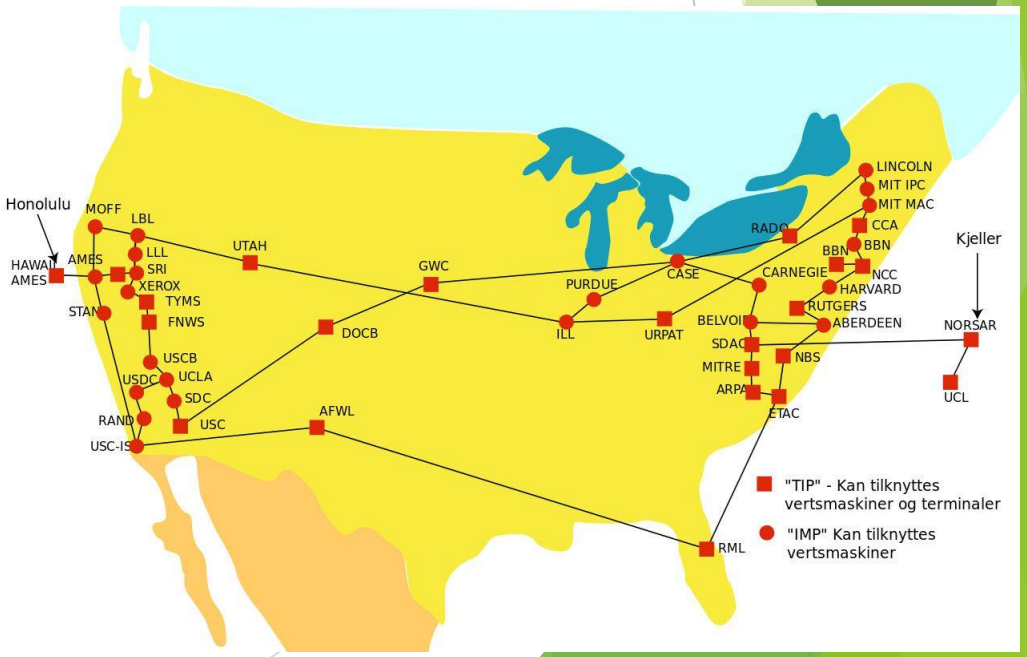
As a circuit-switched network, a dedicated circuit will be established between the caller and receiver prior to the call. Such a process is also called resource reserve and the pathway through switches remains unchanged in the entire call duration. Although PSTN uses a hierarchical network structure but routing decisions are centralized. Calls are typically routed based on the switch hierarchy and predefined paths, and each switch only has access to a limited set of alternative paths. If the most direct path is unavailable or all trunks are busy, calls may not proceed, as the PSTN doesn't dynamically search for alternate physical links in real-time like modern digital networks.



ARPA网
ARPANET

- 鉴于传统电话网络的局限，特别是美苏冷战的背景下，为避免单点打击之后整个通讯网络的中断，同时也为了交换日益增多的信息，美国国防部高级研究计划署开始试验称为ARPANET的网络。ARPANET试验了分组交换的概念，分布式路由的实施，解决了异构网络互联的一系列理论和技术问题，奠定了Internet发展的基础。

Considering the limitations of the traditional telephone network, especially in the set of cold war between the Soviet Union and the United States, the Advanced Research Projects Agency under the Department of Defence of the U.S. launched the design and implementation of the so-called ARPANET, to avoid the interruption even disruption of the communication network caused by single point attack. ARPANET tested the concept of packet-switched network and distributed routing, solved the challenges of inter-connection between heterogeneous networks from theoretical and technological perspectives, hence force laid the foundation for the development of Internet.



互联网
Internet

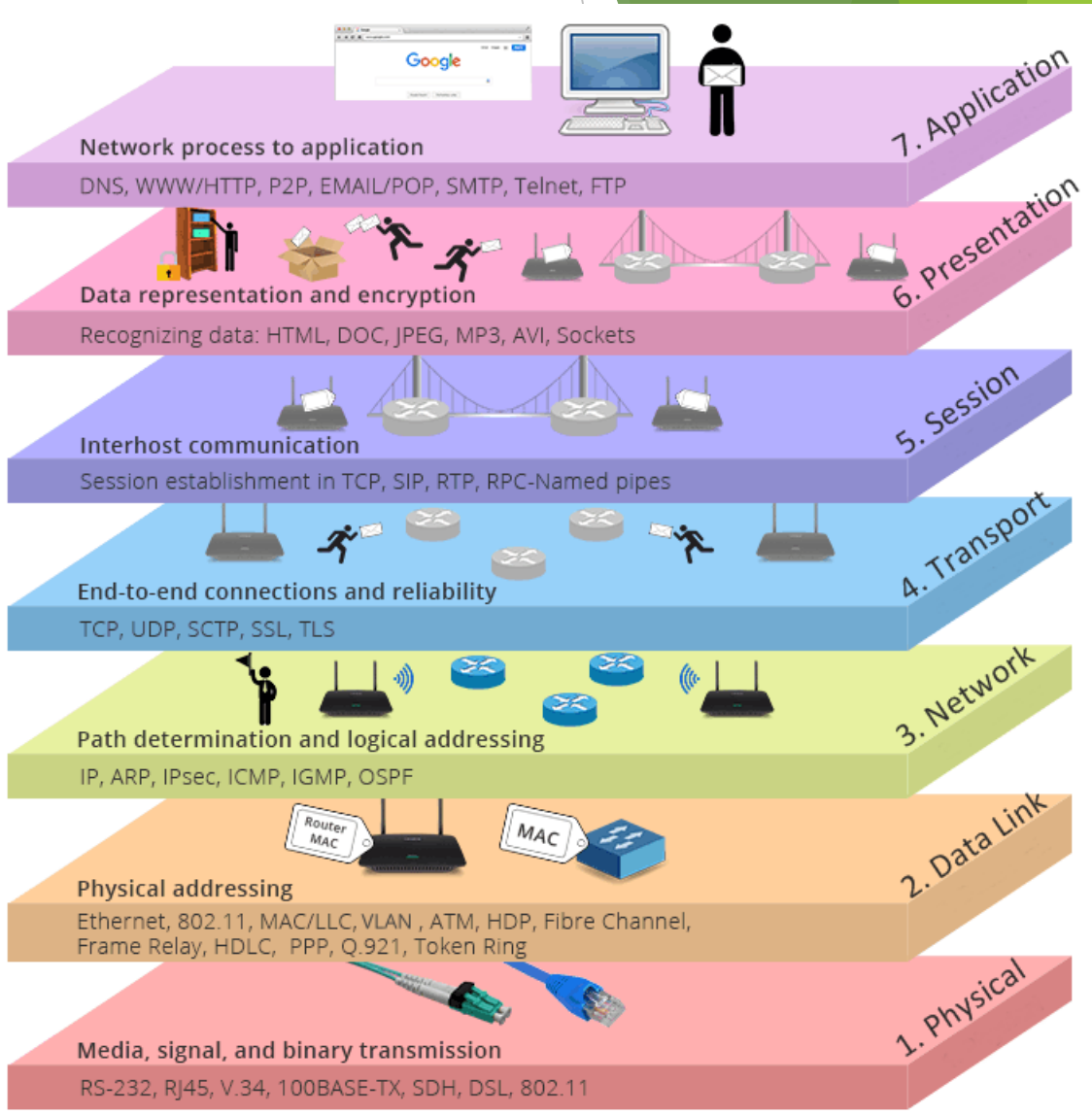
- 实际上，在构建ARPANET时，人们也将在构建复杂系统时积累的理论与经验用在其中，例如模块化的思想。考察通信的过程，人们的谈话需要转变为在终端上的信息表示再到能够在线路上传输的信号，要经过不同媒介的转换。模块化的思想在这里体现为分层的思想，特别是到ARPANET发展的后期阶段，随着并入网络异构性的增加，建立标准化的分层体系架构简化网络设计的一致性与设备厂商的互操作性尤为关键，典型的成果便是开放式通信系统互联参考模型或OSI模型。

  Actually, to construct ARPANET people had employed the theories and experiences accumulated during the build up process of complex systems, for instance, the modularity philosophy. During the communication, conversation between people needs first to be encoded into suitable representations at terminal then converted into the electrical signals which can be transmitted via physical lines, and various media are involved in this process. Especially the later stage of ARPANET, the heterogeneity kept increasing as more networks were merged together. It is more apparent and necessary to standardize the architecture from layer-wise perspective to guarantee the coherence of network design and promote co-operation among devices from different venders, and this consideration led to the Open System Interconnection Reference Model.

OSI模型
OSI Model

- 开放系统互联模型或OSI模型是由国际标准化组织（ISO）在20世纪70年代末提出的，旨在标准化网络通信中使用的各种协议，以便不同计算机系统之间能够实现互联。OSI模型将基于互联网的计算机网络通信协议划分为七层，每一层都负责不同的功能，从物理连接到应用程序的处理，从而更好地实现在不同的系统之间进行网络通信。

The Open System Interconnection Reference Model was proposed by the International Standard Organization (ISO) in late 1970s. By standardizing different protocols in network communication, it is to facilitate inter-connections between different computer systems. OSI model divides the network protocols into seven layers with each layer providing different functionalities, ranging from physical link up to application processing, to promote communication between different systems.



OSI模型
OSI Model

- 下面表格概述了OSI模型的七层的功能描述：

  The following table describes the functionalities of each layer of OSI model:

物理层（Physical Layer）	
由物理传输介质组成，负责在物理介质上传输原始的二进制数据（比特），确保数据在电气、光学或无线信号层面上的正确传输和接收。	It consists of transmission media, to handles the physical transmission of raw binary data (bits) over a medium. It also ensures that data is transmitted and received correctly at the electrical, optical, or radio level.
数据链路层（Data Link Layer）	
其控制对物理介质的访问，确保帧被正确发送到目标设备（通过MAC地址），期间管理帧的同步和流量控制。其也要管理数据帧的编码与解码，提供**错误检测与校正**，确保同一物理网络内节点之间的可靠传输。	Controls access to the physical medium and ensures frames are delivered to the correct device using MAC addresses, meantime Manages frame synchronization and flow control. To achieve this, it manages how data packets are encoded and decoded into bits, and provides error detection, correction, to ensures reliable transmission.

OSI模型
OSI Model

网络层（Network Layer）	
网络层负责路由、寻址和在不同网络之间转发数据包，特别是在跨越多个网络的情况下，确保数据正确传递到目标。为此，该需要负责逻辑地址分配，跨越不同网段时数据包分段和重组等。	It handles routing, addressing, and forwarding of data packets across different networks, especially it involves crossing multiple networks, ensuring that data is delivered to the correct destination. To achieve this, it is responsible for logical addressing, fragmentation and reassembly of packets crossing different types of networks.
传输层（Transport Layer）	
在Best Delivery原则的前提下，确保端到端通信，并根据协议规范，进行源进行数据分段，在目的地进行数据重组。同时，如果协议要求逻辑上的可靠传输，则该层还需要通过丢包重传等功能保证传输的可靠性。防止接收端过载的流控功能也会在该层实现。	Under the Best Delivery principle, to ensures end-to-end communication. It also segments the data at the source and reassembles the data at the destination according to the protocols. Meanwhile, if reliability is required by the protocol, it should provide functionalities such as lost packet retransmission to guarantee it. Further, flow control mechanism tends to be implemented in this layer to prevent overwhelming the receiver.

OSI模型
OSI Model

会话层（Session Layer）	
管理应用程序之间的会话或连接，包括会话的建立、维持与终止。控制系统间通信的对话，包括何时以及如何发送数据，如何同步，等等。	It manages sessions or connections between applications, for instance, establishing, maintaining, and terminating sessions. It also controls dialog between systems, including data sending, data synchronization.
表示层（Presentation Layer）	
通过处理数据的编码、加密和压缩，确保数据以应用程序可用的格式呈现。同时，包括数据压缩、数据加密与解密等。	It ensures that data is in a usable format for the application by handling data encoding, encryption, and compression. It also includes data compression, data encryption and decryption, etc.
应用层（Application Layer）	
该层充当用户与网络之间的接口，直接向终端用户应用程序提供网络服务。例如，提供API和协议以支持通信，支持电子邮件、文件传输、网页浏览等应用。	It acts as the interface between the user and the network, to provide network services directly to end-user applications. For instance, it provides APIs and protocols for communication, and supports applications like email, file transfer, and web browsing.

OSI模型
OSI Model

- 需要指出的是，OSI模型作为一个概念性框架，用作网络协议和软件设计的指南，但由于OSI模型过于强调设计的完备性而没有考虑当时的实际情况，OSI模型并没有真正流行起来，但OSI模型在计算机网络领域仍然是一个重要的教学和分析工具。

  As a conceptional framework to guide network protocol and software design, OSI over-emphasized the completeness and overlooked the reality, incurring its inferiority in practice. However, OSI model still plays an important role from pedagogical and analytical perspective.

- 实际上，在OSI模型制定之前，ARPANET使用的是网络控制协议或NCP来组网。但随着网络的发展和用户对网络的需求不断提高，设计者们发现，NCP协议存在着很多的缺点以至于不能充分支持ARPANET网络。后来，学者设计了传输控制协议/网际协议或TCP/IP，来实现在各种硬件和操作系统等异构网络上的操作，从而大大增加了联网能力。

  Actually, before the proposal of OSI model, the Network Control Protocol or NCP was invented to implement the ARPANET. However, as the blossom of the network and demanding from users, the designers noticed the downsides of NCP constrained the development of ARPANET. Later, scholars designed the Transmission Control Protocol/Internet Protocol or TCP/IP suite, to facilitate networking operations on different hardware and operating systems, hence greatly increase the capacity of interconnected networks.

TCP/IP模型
TCP/IP Model

- 下面表格概述了TCP/IP模型的四层的功能描述：

  The following table describes the functionalities of each layer of TCP/IP model:

网络接口层（Network Interface Layer）	
其负责设备间数据的物理传输，负责定义数据如何通过硬件（如电缆或无线信号）传输，包括帧的创建、MAC 地址解析以及硬件层面的错误检测。	It handles the physical transmission of data between devices in a network, which is achieved by dealing with frame creation, MAC addressing, and error detection at the hardware level.
网络层（Internet Layer）	
其负责逻辑寻址和路由，确保数据包到达目的地。通常工作包括为设备分配逻辑地址，基于IP地址进行网络间的数据路由，负责数据包的分片和重组。	It handles logical addressing and routing to ensure data packets reach their destination, tasks of this layer includes assigning logical addresses to devices (IP addresses), routing data between networks using IP addresses, and fragmenting and reassembling packets for transmission.

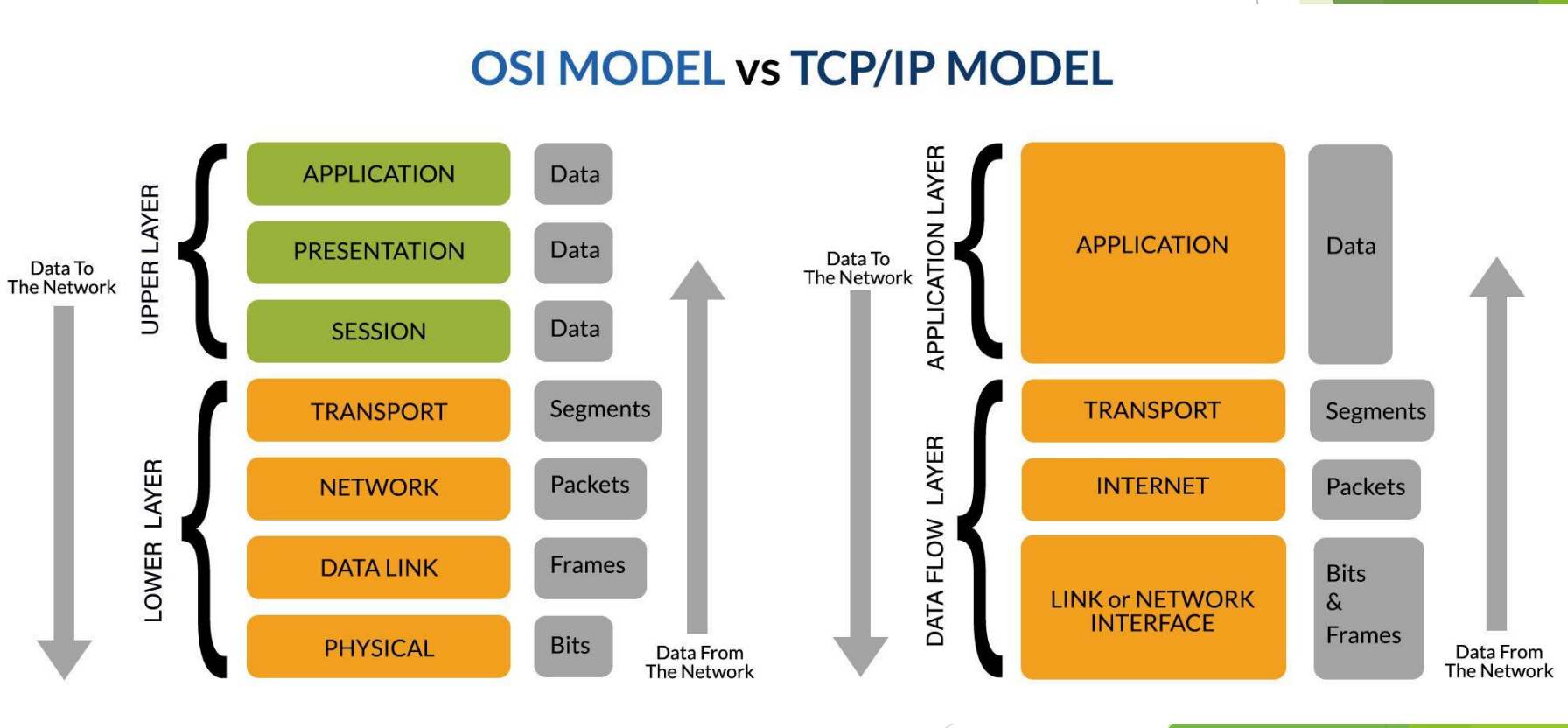
TCP/IP模型
TCP/IP Model

传输层（Transport Layer）	
管理设备之间的端到端通信，确保可靠的数据传输，包括提供错误检查和数据恢复功能（可靠传输），将数据流分割为数据段并重新组装，在源设备和目标设备之间建立和维护连接。	It manages end-to-end communication between devices, ensuring reliable data transfer, Tasks include error-checking and data recovery (reliable transport), segmentation and reassembly of data streams, establishment and maintenance of connections between source and destination.
应用层（Application Layer）	
为用户和应用程序提供网络服务，负责应用程序与下层协议之间的通信。确保数据的正确格式化和传输。	It provides network services to end-users and applications. Functions include facilitating communication between user applications and lower layers, ensuring proper formatting and data transfer for application-level protocols, etc.

模型对比
Model Comparison

- OSI模型的七层架构与TCP/IP模型四层架构，其对比如下图所示：

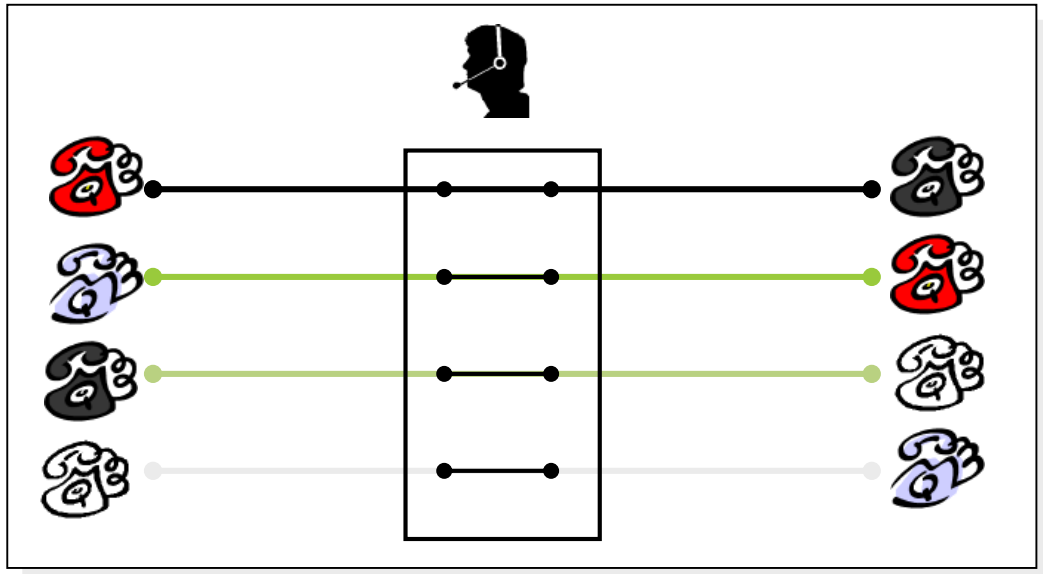
The comparison of the seven layered OSI model and the four layer TCP/IP model are on the right:

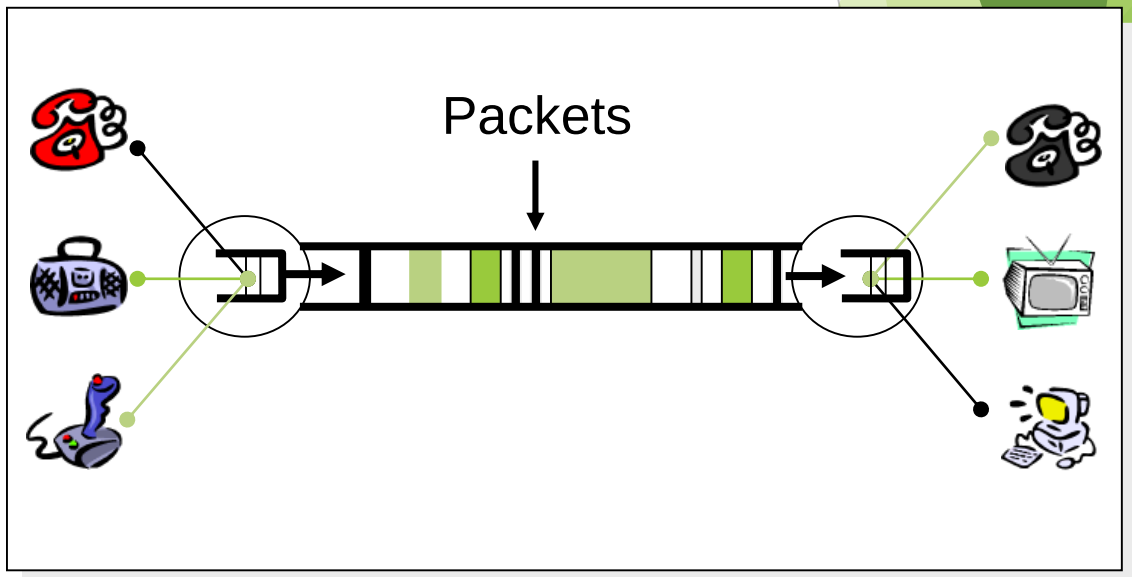


网络对比
Network Comparison

- 在前面的基础上，我们再从交换的角度对比一下公共交换电话网与计算机网络，更好地了解电路交换与包交换的不同之处。

  Based on what we have delivered, let's compare the public switched telephone network and computer network again from the switching perspective to better understand the difference between circuit switching and packet switching.

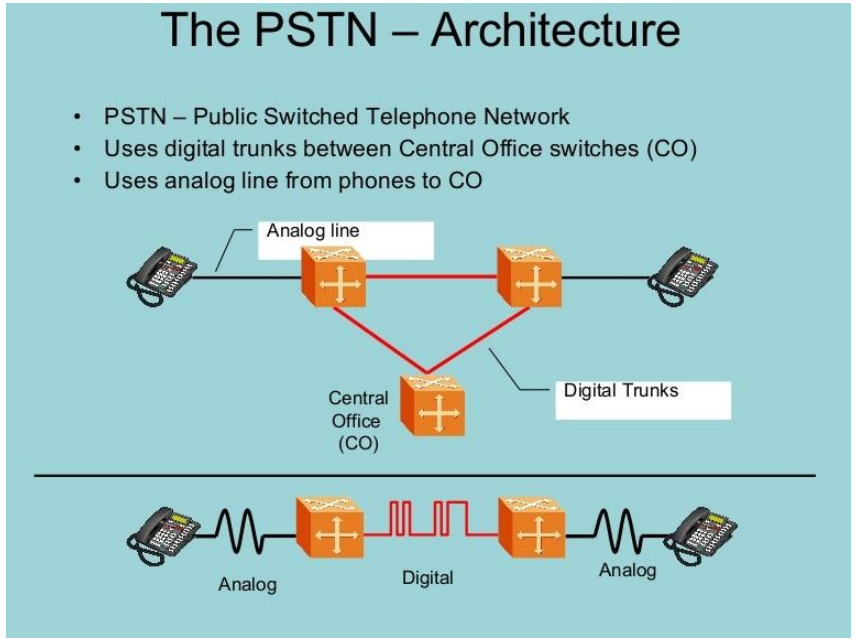


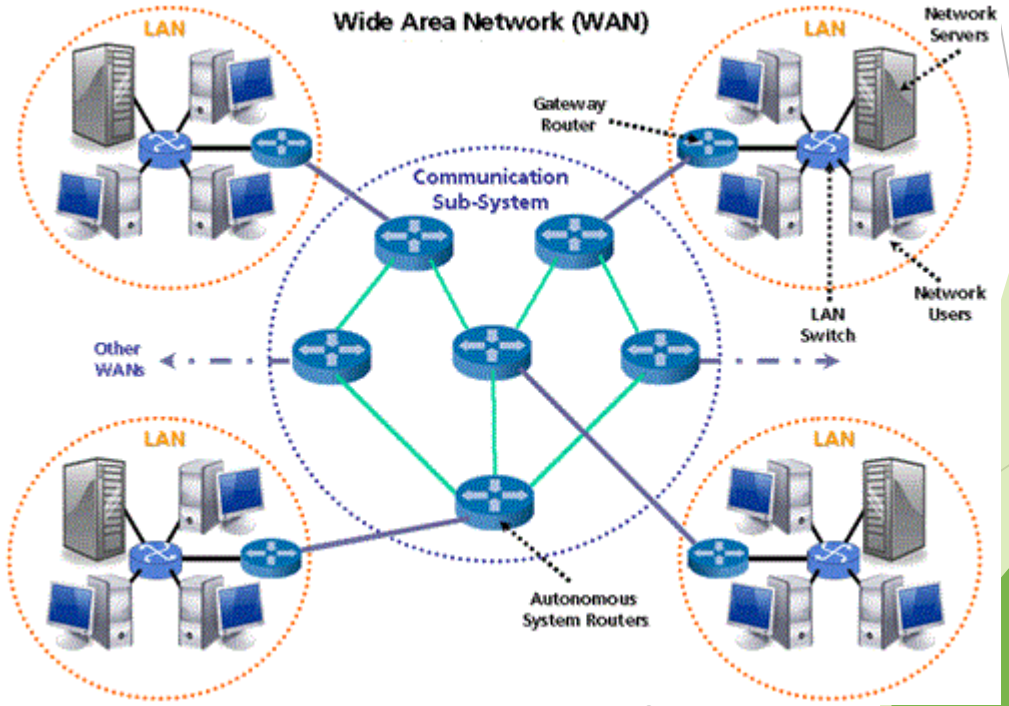


网络对比
Network Comparison

- 这种交换机制的不同，在一定程度上也决定了组网方式或网络结构的差异。

  The switching mechanism to some extent determines the architecture of the network.

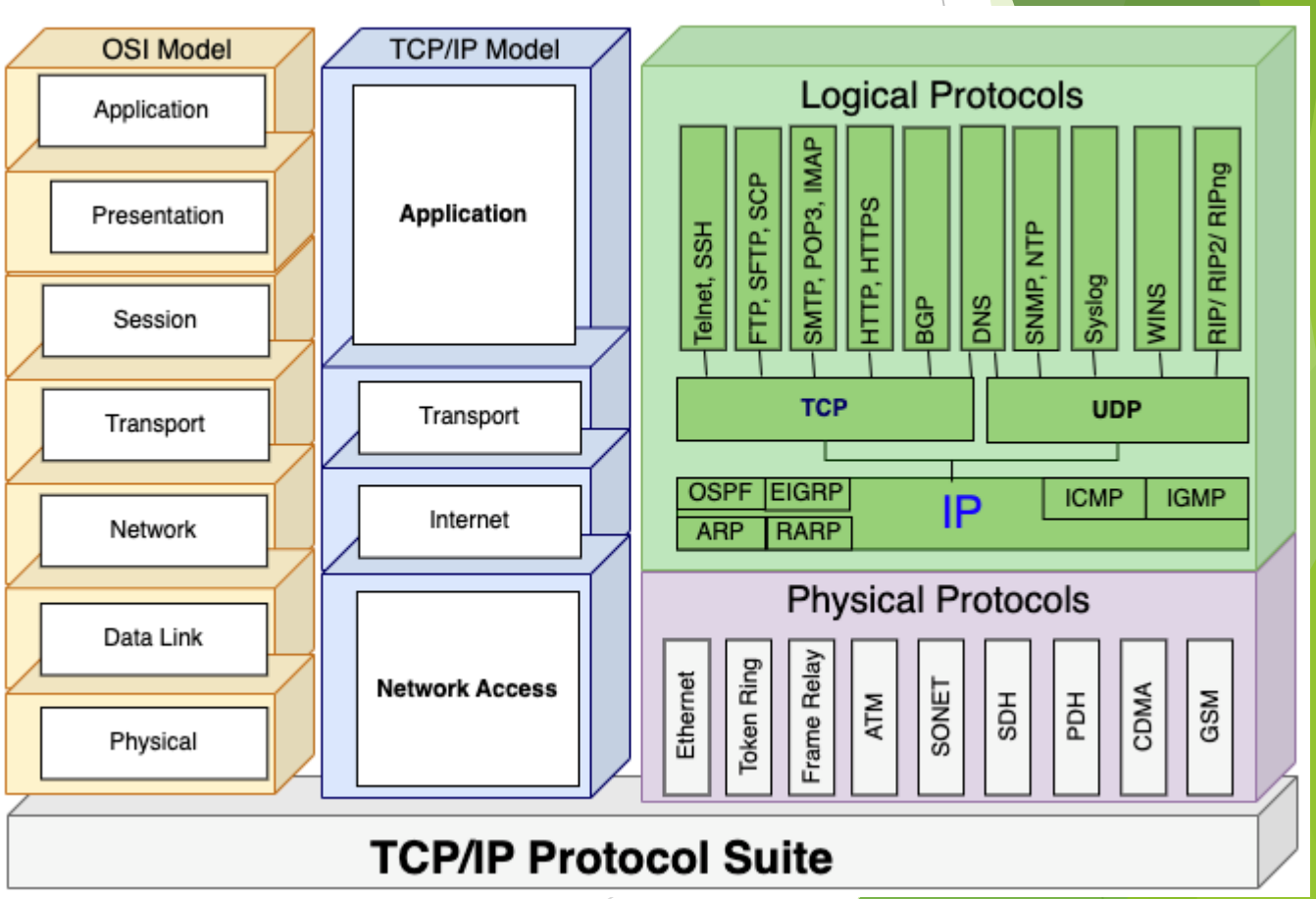




TCP/IP协议集
TCP/IP Suite

- 实现TCP/IP模型的一系列协议的集合统称TCP/IP协议集。尽管狭义的情况下其倾向于指由互联网工程任务组IETF制定的一系列RFC，但广义上由其他标准化组织制定的与网络相关的一些标准也隶属于TCP/IP协议集。

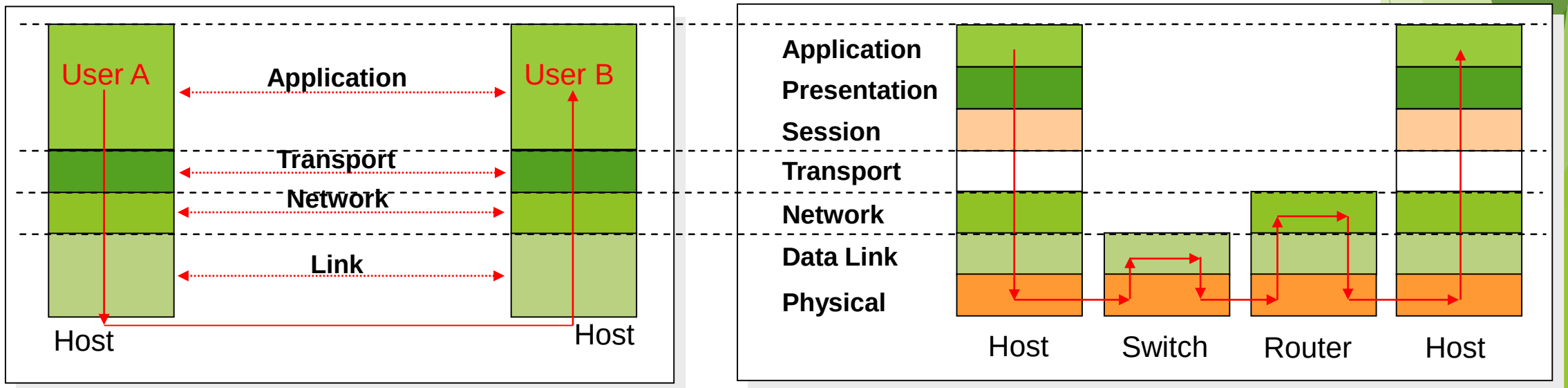
  The collection of protocols which implements the TCP/IP model are termed TCP/IP suite. In a narrow sense, it only refers to the series of RFCs made by the Internet Engineering Task Force or IEFT, however in a general sense, standards concerning computer networking proposed by other bodies are also attributed to the TCP/IP suite.



分层
Layering

- 无论是OSI模型还是TCP/IP模型，其分层设计不仅带来了网络设计的简化，而且为网络节点的功能设计提供了明确的参考。下图是节点设备或主机通信的从层的观点的图示，以及所涉及的中间设备的图示：

  No matter OSI model or TCP/IP model, the layering design not only brings the simplification of network design, but also provides well-defined reference for functionality design of network nodes. The following figures show the communication between hosts from layering perspective, as well as the communications involving intermediate nodes.



TCP/IP协议集
TCP/IP Suite

- 由于计算机网络比传统通信网络的异构性更加明显，因此，TCP/IP协议集包含众多的协议。通常情况下，特别是从应用的角度，了解网络层的IP协议，与传输层的TCP与UDP协议便可以处理大多数的应用场景。

  The more obvious heterogeneity of computer network than tele-communication network incurs much more protocols or standards for TCP/IP suite. Generally, especially from the application perspective, a good understanding of the IP protocol of the Network Layer, the TCP and UDP protocols of the Transport Layer is sufficient enough for most scenarios.

- 计算机网络的一个最重要的特点，即包交换，是由网络协议IP保证的。其负责在网络设备之间进行数据包的地址定位和路由，确保数据包能够送达目的地。由于通信的端点之间可能存在多条路径，网络协议不保证由一个端点发出的数据包按顺序到达或无误。

  One eminent characteristic of computer networking is packet switching, which is achieved by the Internet Protocol (IP). It is responsible for addressing and routing packets of data between devices on a network, to ensure that data packets are delivered. Because there might be multiple routes between the endpoints, the protocol will not guarantee that packets sent out by one endpoint sequentially arrive in order or without any error.

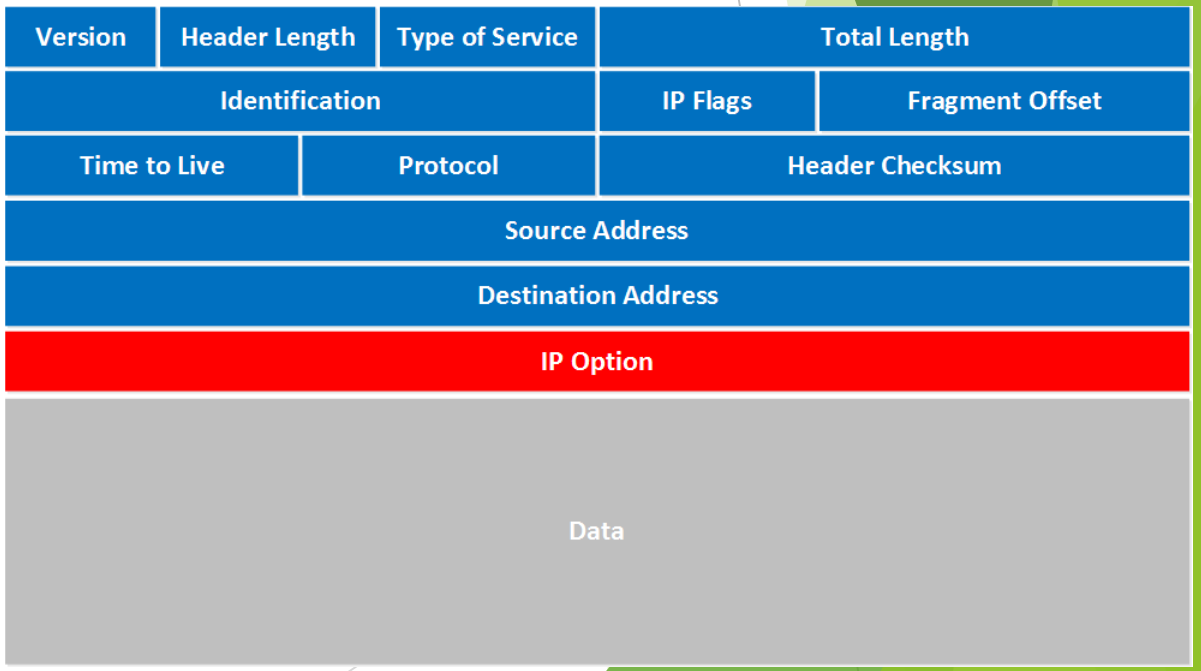
TCP/IP协议集
TCP/IP Suite

- IP是互联网通信的基础，与其相关的一个重要概念是IP地址。类似于数字化的家庭地址，原则上每个联网设备都有一个唯一的IP地址。网络设备依靠IP地址进行寻址和路由，在设备之间传输数据。IP协议有个版本，即IPv4和IPv6，分别对应32位地址与128位地址。

  IP is the backbone of communication on the Internet, and one concept associated with it is the IP address. Like a digital home address, every device on a network has a unique IP address. The network devices are addressing and routing data packets according to the IP address. Currently, there are two versions, IPv4 and IPv6, corresponding to addresses with 32-bit and128-bit addressing.

- 右图是IPv4报文头部的定义，这些域共同保证单个数据包在网络上正确地寻址与路由。

  The right figure shows the definition of the IPv4 header, all the fields ensure the addressing and routing for the current packet.



TCP/IP协议集
TCP/IP Suite

- 传输层协议以TCP和UDP为代表。TCP作为传输控制协议，可以在非可靠的网络层传输的基础上提供可靠的传输服务。其通过错误检查和丢包重传机制，确保所有数据准确无误地传输且按顺序到达。尽管IP协议本身是无连接的，但TCP是面向连接的，这意味着在通信之前要建立虚拟连接。与TCP相关的一个重要概念是端口，通过IP地址与端口，在同一个主机上可以标识参与与远端节点通信的不同的应用程序，实现多路复用，提高通信的效率。

  The most common protocols for Network Layer is TCP and UDP. As Transmission Control Protocol, it provides reliable transmission service based on the unreliable transmission of the Network Layer. By integrating functionalities such as error checking and data retransmission, etc., it ensures data integrity and guarantees that data arrives in the correct order. Although IP protocol is connection-less, however, the connection-oriented characteristic of TCP means a connection must be established before data transfer starts. One concept associated with TCP is port. By combining IP address, the pairs can be used to label different applications communicating with different peers running on the same host, to multiplexing the physical link to guarantee the communication efficiency.

TCP/IP协议集
TCP/IP Suite

- 另一个典型的传输层协议是用户数据报协议UDP。UDP无需建立连接，直接发送数据，因此速度较快；但由于没有错误检查，也不保证数据一定到达或按顺序到达，因此可靠性低 。所以UDP适用于对速度要求高但对偶尔数据丢失不敏感的场景。

Another typical protocol for Transport Layer is User Datagram Protocol. It just sends the data without setup, hence it is faster; No error-checking or guarantee of delivery or order means it is less reliable. It best suits for scenarios where speed is more critical than accuracy.

- 右图是TCP协议与UDP协议的报文头部信息。

The right figure illustrates the header information for TCP and UDP respectively.

TCP Segment Header Format

Bit #	0 – 7	8 – 15	16 – 23	24 – 31
0	Source Port		Destination Port	
32	Sequence Number			
64	Acknowledgment Number			
96	Data Offset	Res	Flags	Window Size
128	Header and Data Checksum		Urgent Pointer	
160...	Options			

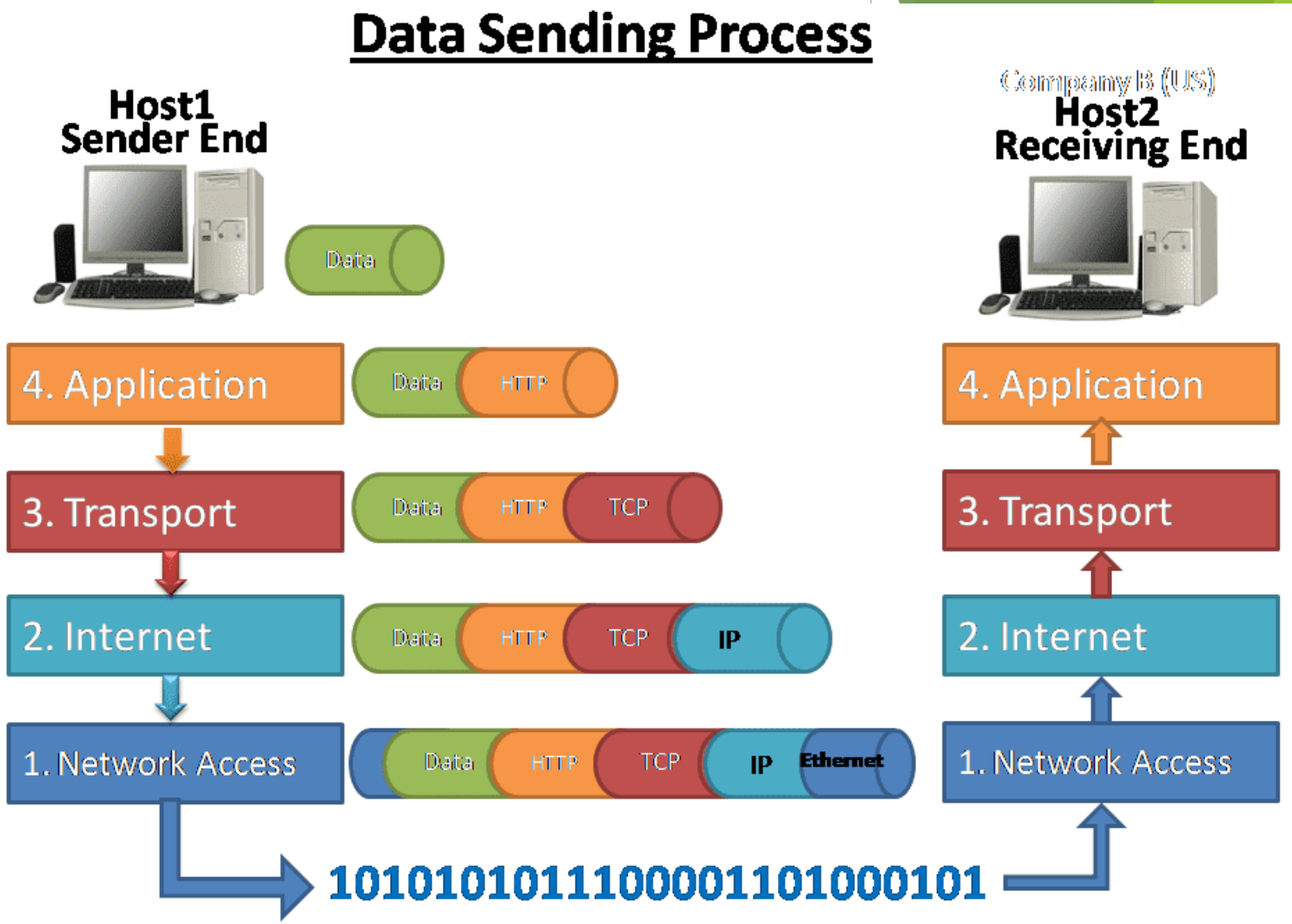
UDP Datagram Header Format

Bit #	0 – 7	8 – 15	16 – 23	24 – 31
0	Source Port		Destination Port	
32	Length		Header and Data Checksum	

TCP/IP协议集
TCP/IP Suite

- 在网络通信中，在用户数据沿着协议栈向下传递的过程中，各层协议会根据规范要求，依次添加合适的报头；在接收端，这些报头再依次除去，如右图所示：

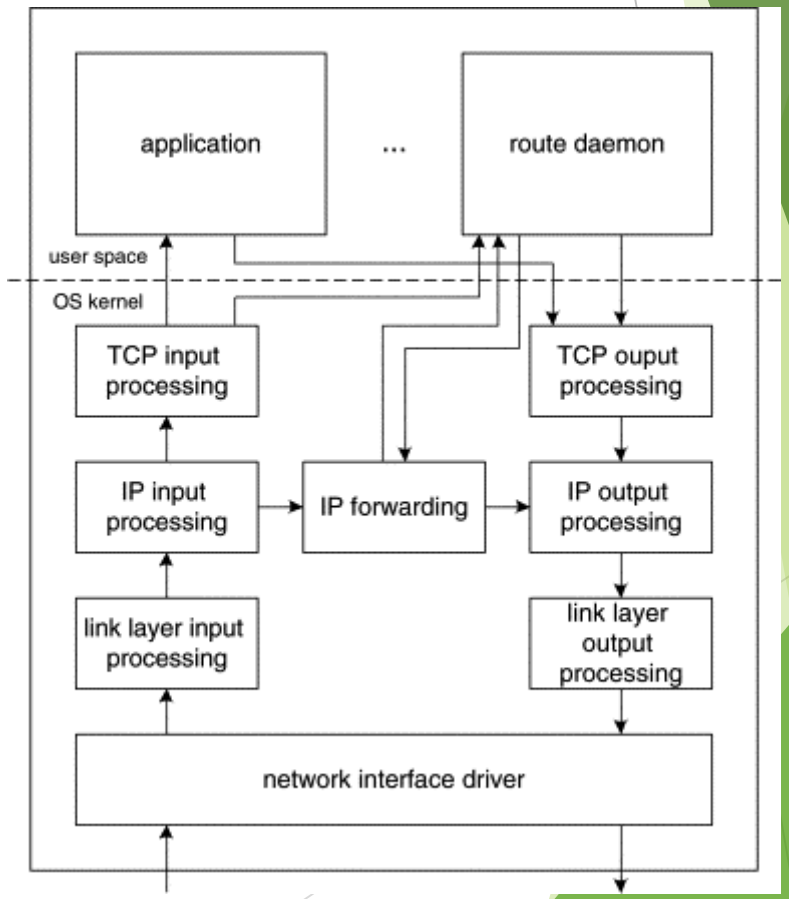
  During network communication, user data passes through the all the layers, with each layer adds its own header whenever it sees appropriate. And at the receiver end, the headers are stripped accordingly, just illustrated in the right figure:



TCP/IP协议集
TCP/IP Suite

- 在操作系统实现的具体对网络通信的支持中，传输层及以下的部分一般实现在了内核层，而与应用层相关的一般实现在了用户态。用户态的应用程序通过变成接口与内核态交互，实现通讯中的收发包功能，其如右图所示。最流行的网络编程接口即套接字编程接口（Socket API）。

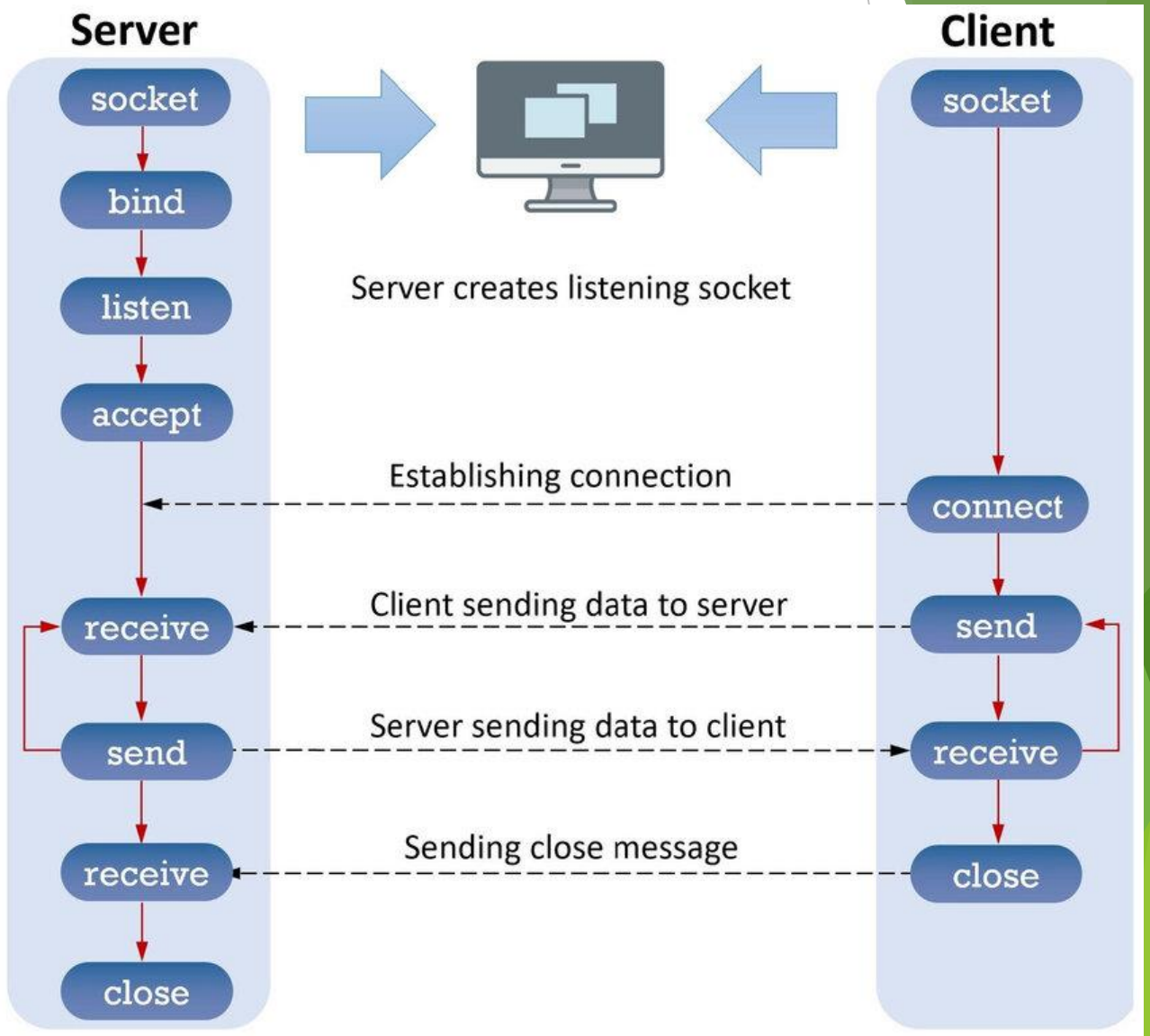
  During the implementation of network communication in Operating Systems, the Transport Layer and layers below tend to be implemented in the kernel space, and the Application Layer gets implemented in the user space. Programs interact with kernel service by application programming interface, to send or receive packets, as shown in the right. The most popular network programming interface is the socket API.



套接字编程
Socket Programming

- 通常，在基于套接字的编程中，采用的是客户机/服务器模式，根据所采用的范式是客户机与服务器，其范式或所采用的API有所不同。同时，还要考虑是基于TCP的编程与基于UDP的编程。右图展示了基于TCP编程时，客户机与服务器的范式：

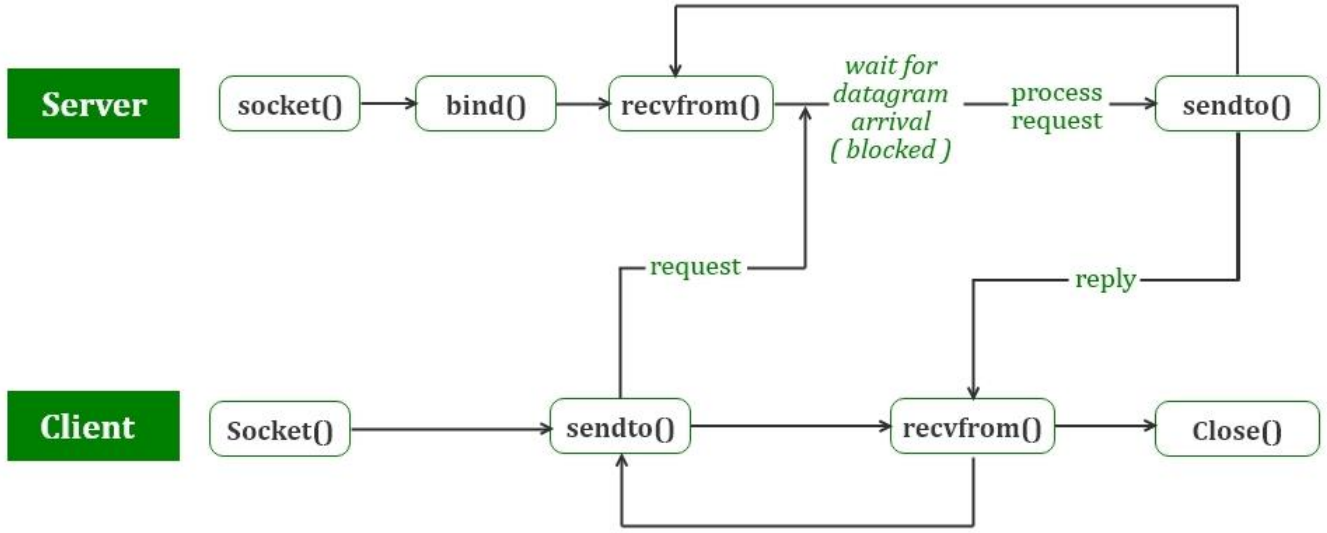
  Usually, socket-based programming adopts the client/server architecture. According to the role, client or server adopt different APIs. Meantime, based on underlying protocol, aka., TCP or UDP, the paradigm can also be different. The right figure shows the paradigm of client and server if TCP is used.



套接字编程
Socket Programming

- 下图展示了基于UDP编程时，客户机与服务器的范式。读者可以与TCP的情况作对比，体会两者的差别：

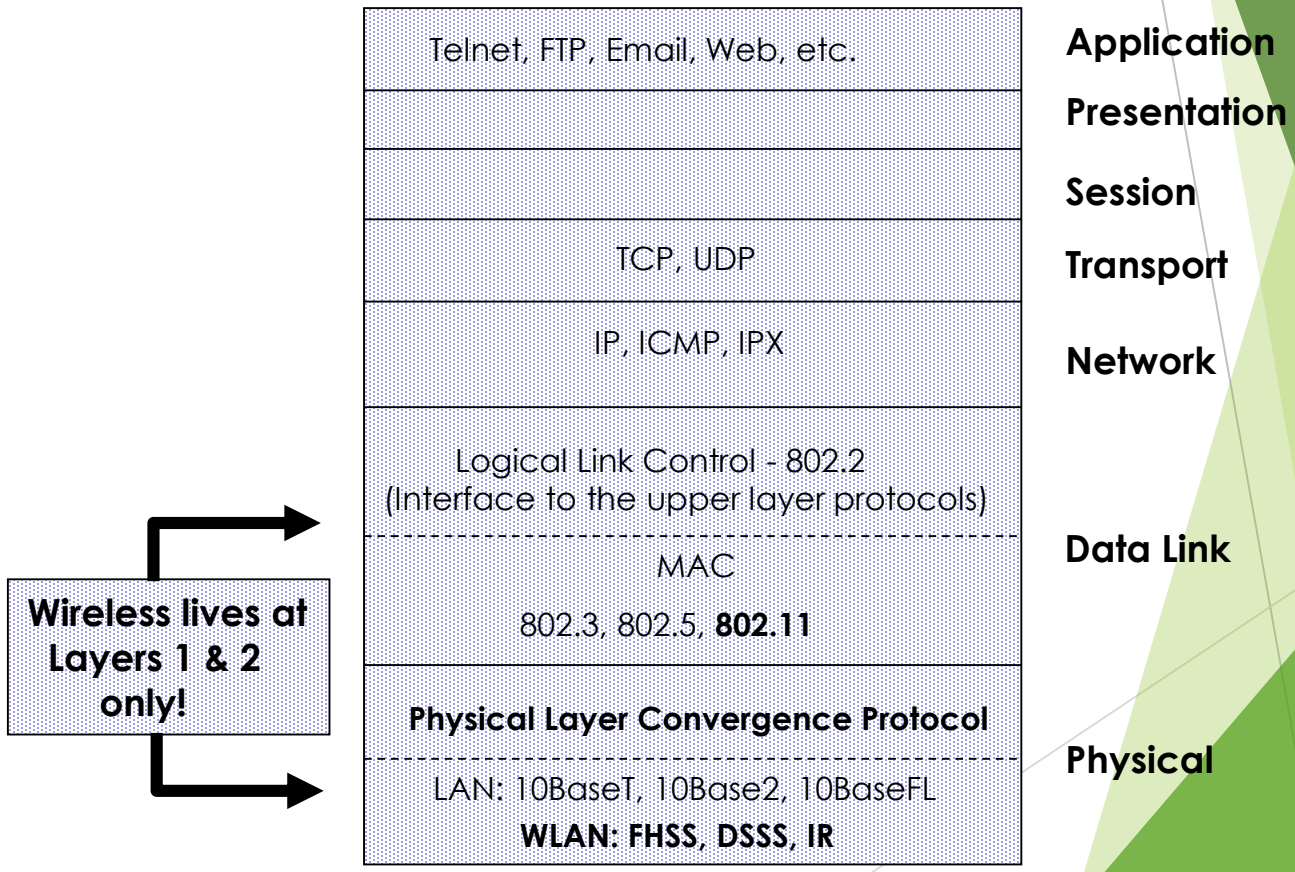
  The below figure shows the paradigm of client and server if UDP is used. User can compare it with the case of TCP to figure out the different between the two:



WIFI总览
WIFI Overview

- 随着技术的发展，网络接入方式，特别是对于终端而言，逐渐由有线向无线转变。最常用的无线接入即通常的WIFI，其与OSI模型的关系如右图所示：

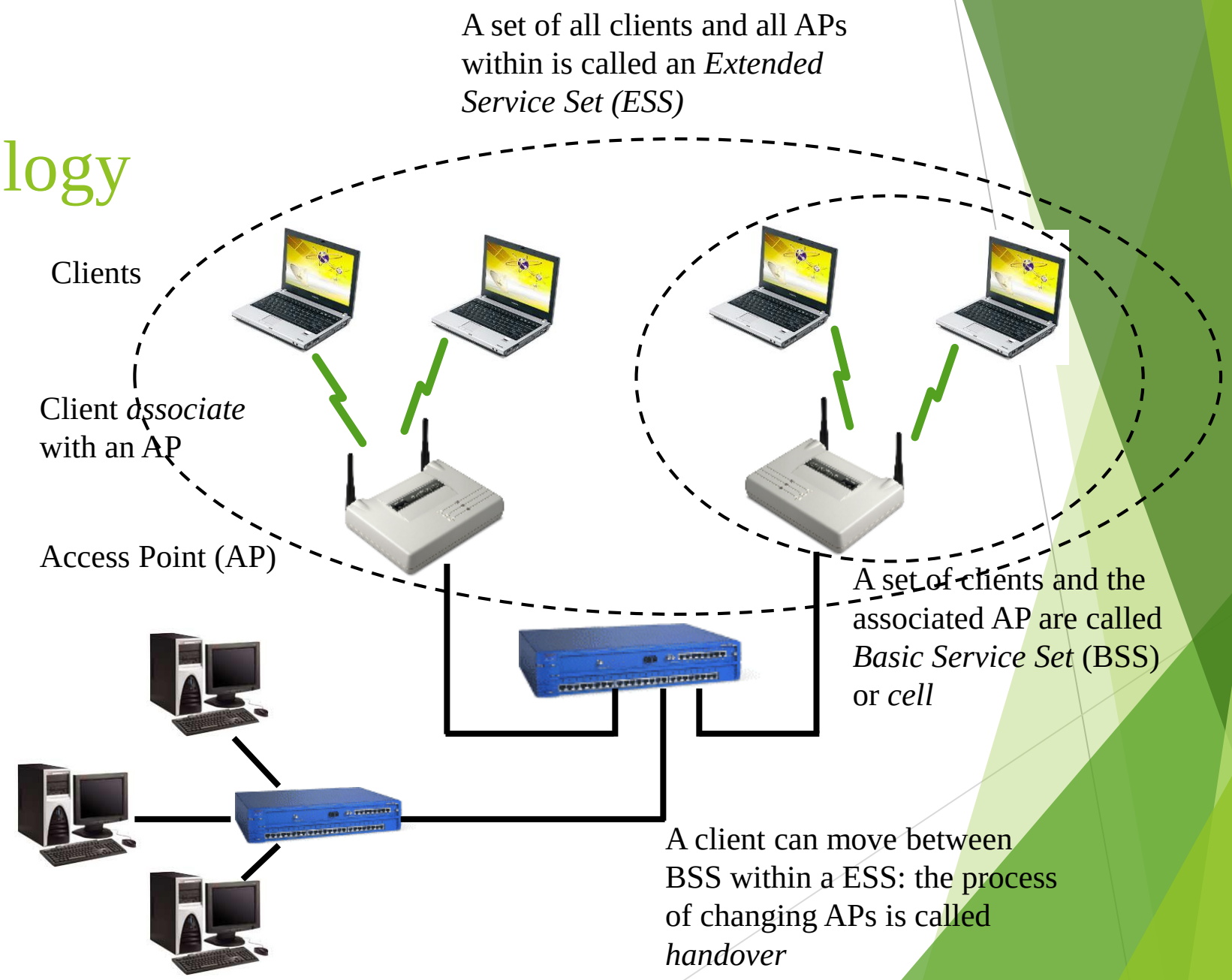
  As the evolvement of technologies, especially for terminals, the network access methods gradually shift from wiring to wireless. The most commonly-used way is WIFI. Its relation with the OSI model is as in the right figure:



WIFI术语
WIFI Terminology

- WIFI中常见的概念与术语如右图所示：

  The commonly-used concepts and terminologies are shown in the right:

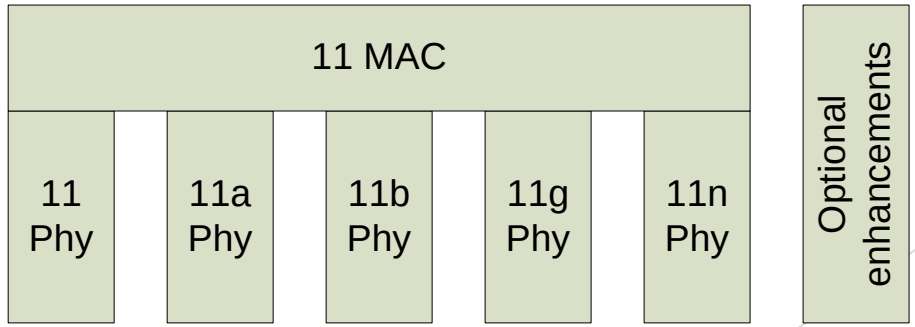


WIFI协议
WIFI Protocols

- WIFI相关的技术规范主要在802.11系列标准中定义，其囊括了：
  - 多个物理层标准（最初定义的，a、b、g、n）；
  - 单一的MAC层标准，通适于不同的物理层；
  - 可选的增强标准：服务质量（11e）、频谱（11k、11j）、安全（11i）等等

The WIFI related technical specs are defined in the 802.11 protocol series, including:

- Multiple Physical layer standards (original, a, b, g, n)
- Single MAC protocol standard, common across different physical layers
- Optional enhancements, E.g. quality of service (11e), spectrum (11k, 11j), security (11i), …



IEEE 802.11 Wireless LAN Standards

WIFI协议
WIFI Protocols

- IEEE 802.11中的物理层提供了在无线媒介上传输数据的方式，其媒介访问控制层定义了发现、加入、离开服务集（BSS）的管理过程，同时也制定了在无线媒介上高效与稳健地传输数据的方法。相关过程涉及的包如右图所示：

  IEEE 802.11 Physical layer provides means for sending data over wireless medium. IEEE 802.11 MAC layer defines management procedures for discovering, joining and leaving BSS/ESS. It also specifies how communication occurs efficiently and robust over wireless medium. The packets for involved procedures are as in the right figure: