Unit II-Cloud Enabling technology and Virtualization

Cloud-Enabling Technology: Broadband Networks and Internet Architecture, Data Center Technology, Virtualization Technology, Web Technology, Multitenant Technology, Service Technology.

Implementation Levels of Virtualization, Virtualization Structures/Tools and Mechanisms, Types of Hypervisors, Virtualization of CPU, Memory, and I/O Devices, Virtual Clusters and Resource Management, Virtualization for Data-Center Automation.

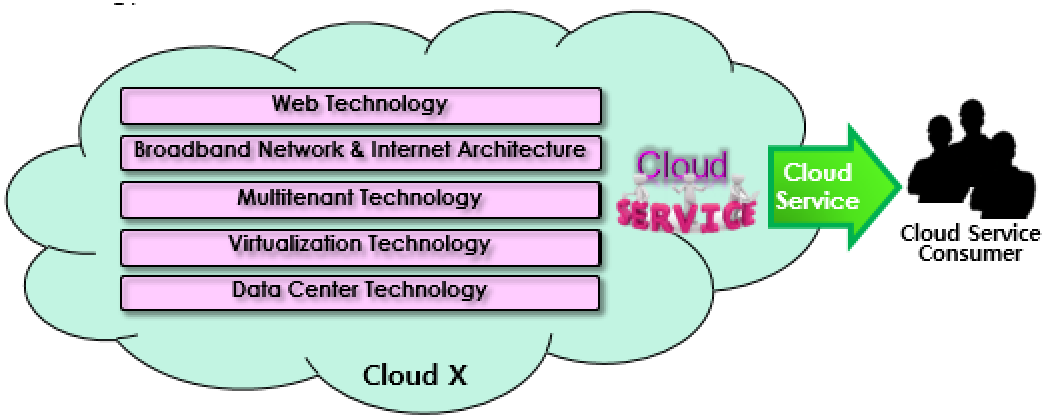
Agenda

- Broadband Networks and Internet Architecture,
- Data Center Technology,
- Virtualization Technology,
- Virtualization Structures/Tools and Mechanisms,
- Types of Hypervisors,
- Virtualization of CPU, Memory, and I/O Devices,
- Virtual Clusters and Resource Management,
- Virtualization for Data-Center Automation.

Cloud Enabling Technology

- **Integrated technology**
  - Not something entirely new – combined of & integrated from a number of existing technologies
  - Integrating a number of existing core technologies into a single service – already matured and some of them more evolved on the way

- **Existing technologies enabled cloud computing include:**
  - Broadband networks & internet architecture
  - Data center technology
  - Virtualization technology
  - Web technology
  - Multitenant technology
  - Service technology



Data Center Technology

- **Data center**
  - Grouping IT resources in close proximity with one another (rather than having them geographically dispersed) for power sharing, higher efficiency in shared IT resource usage and improved accessibility for IT personnel – reason for popularizing data center concept
  - Characterized for centralized IT resources such as servers, storages, databases, networking & telecommunication devices and software solutions via applying a number of technologies

Data Center Technology

- **Standardization and modularity**
  - Built upon standardized **commodity hardware** and designed with modular architecture
  - Aggregating multiple identical building blocks of facility infrastructure and equipment to support **scalability, growth and speedy hardware** replacements
  - **Reduces investment and operational costs** as they enable economies of scale for the procurement, acquisition, deployment, operation and maintenance processes
  - IT resource consolidation favored by common **virtualization strategies** and the constantly **improving capacity and performance** of physical devices

Data Center Technology

- **Virtualization**
  - Virtualization: an **abstraction layer** with mapping or redirection capability
  - Physical IT resources: the facility infrastructure that houses computing/networking systems and equipment, together with hardware systems and their operating systems
  - Virtual IT resources: comprised of operational and management tools that are often based on virtualization platforms that abstract the physical computing and networking IT resources as virtualized components that are easier to allocate, operate, release, monitor and control
- **Automation**
  - Reduces operational costs and the error rate in data center via automated management without human supervision – provisioning, configuration, patching and monitoring
  - Enables self-configuration and self-recovery – basis of automatic computing technology

Data Center Technology

- **Remote operation and management**
  - Most operational and administrative tasks of IT resources in data center can be **commanded through the network's remote** (within data center boundary in general) **consoles and management systems.**
  - Most operational and administrative tasks carried out from the control room in data center except for those requiring physical operations such as hardware jobs or cabling.

Data Center Technology

- **High availability**
  - All resources in data center are subject to fail anytime based on current hardware and software technologies.
  - Most resource failures **affect service continuity and underlying business** as well.
  - In general, data center provides **fail-safe technologies** mainly based on redundancy in every possible layer – **fault-tolerant or fault-resilient** technologies on top of redundant resources: power supply, cabling, networking, servers, storages and software licenses.
  - Fault-avoidance technologies: load balancing, scaling-up/down, etc.

Data Center Technology

- **Security-aware design, operation and management**
  - The level of security determines the **credibility of the given data center**.
  - Security issue is the main concern that prohibits many organizations from migrating their IT resources from on-premise to cloud-based.
  - Security threats that make organizations hesitate to outsource IT environment are two-fold: possible malicious attack from outside and anxiety about keeping data outside of organization’s physical boundary (not only business-wise but also legality-wise).
  - Various levels of protection and security mechanisms:Physical Security: Network Security:Redundancy & Disaster Recovery, Access Control: Data Encryption network isolation, firewalls and monitoring tools

Data Center Technology

- **Facilities**
  - Typically **custom-designed computing resources, storages and network equipment** for the given purpose
  - Several functional layout areas based on power supplies, cabling, environmental control stations that **regulate heating, ventilation, air conditioning, fire protection, (physical) security & access control system, monitoring system,** etc.

Data Center Technology

- **Computing hardware**
  - Mainly composed of standardized commodity servers with a number of computing hardware technologies such as:
    - Rack technology – standardized rack with interconnects for power, network, and internal cooling, efficient use of space,
    - CPU architecture – support for various CPU types: x86-32bits, x86-64bits, RISC, CISC, etc.
    - Multi-core CPU architecture – hundreds of physical & logical processing core in single unit of standardized racks
    - Redundancy & hot-swap technology – hard disks, power supplies, network interfaces, storage controller cards, etc.

Data Center Technology

- **Computing hardware**
  - Blade server technologies with rack-embedded physical interconnections (blade enclosures), fabrics (switches), power supply units, cooling fans, etc.
  - Maximizes and enhances inter-component networking and management while **optimizing physical space & power** via individual server hot-swapping, scaling, replacement and maintenance
  - Benefits the deployment of fault-resilient (tolerant) systems based on cluster technology
  - Several industry-standard and proprietary operational and management software tools that configure, monitor, and control hardware IT resources from remote & centralized consoles – self-provisioning
  - Hundreds or even thousands of physical or virtual servers (IT resources) operated by a single operator

Data Center Technology

- **Storage hardware**
  - Needs to deal with tons of data created every day – easily reaching PBs of total scale in general
  - One of the most difficult task to deal with in data center and many different levels of technologies for fast access, data availability, massive data accommodation, etc.:
    - RAID (Redundant Array of Independent/Inexpensive Disks) – integrating hundreds of individual HDD to provide fast, reliable, massive storage space
    - IO caching – at different layers: storage controllers, each physical/virtual servers, separate caching servers
    - Hot-swapping – replacing faulty HDD without requiring prior power down (a part of RAID technology)
    - Storage virtualization – abstracted storage layer creating virtual storage device free from the physical property of member storage devices
    - Data replication – memory snapshot,(A snapshot of active processes and memory contents is taken.) volume cloning, mirroring, Distaser Recovery, Continuous Data Protection, etc.
    - Distributed storage – file, block, object-level distributed storage: HDFS, Ceph, etc.

Data Center Technology

- Storage Topology
  - DAS (Direct Attached Storage): storages directly attached to a host system via block-level channel protocol such as SCSI/FC
    - **Example**: A hard drive connected directly to a server.
  - NAS (Network Attached Storage): storages attached to a number of host systems via file-level network protocols such as NFS/CIFS/SMB – while providing file-level data sharing among multiple hosts
    - **Example**: A file server providing shared storage to a group of employees within an organization.
  - SAN (Storage Area Network): storages attached to multiple hosts via block-level network protocols such as Fibre Channel, Infiniband, iSCSI, etc.
    - **Example**: A large-scale enterprise environment with multiple servers accessing a centralized block-level storage system.
- Data backup issues in data center-Backup Window and Time Constraints, Data Redundancy, Security and Encryption

Data Center Technology

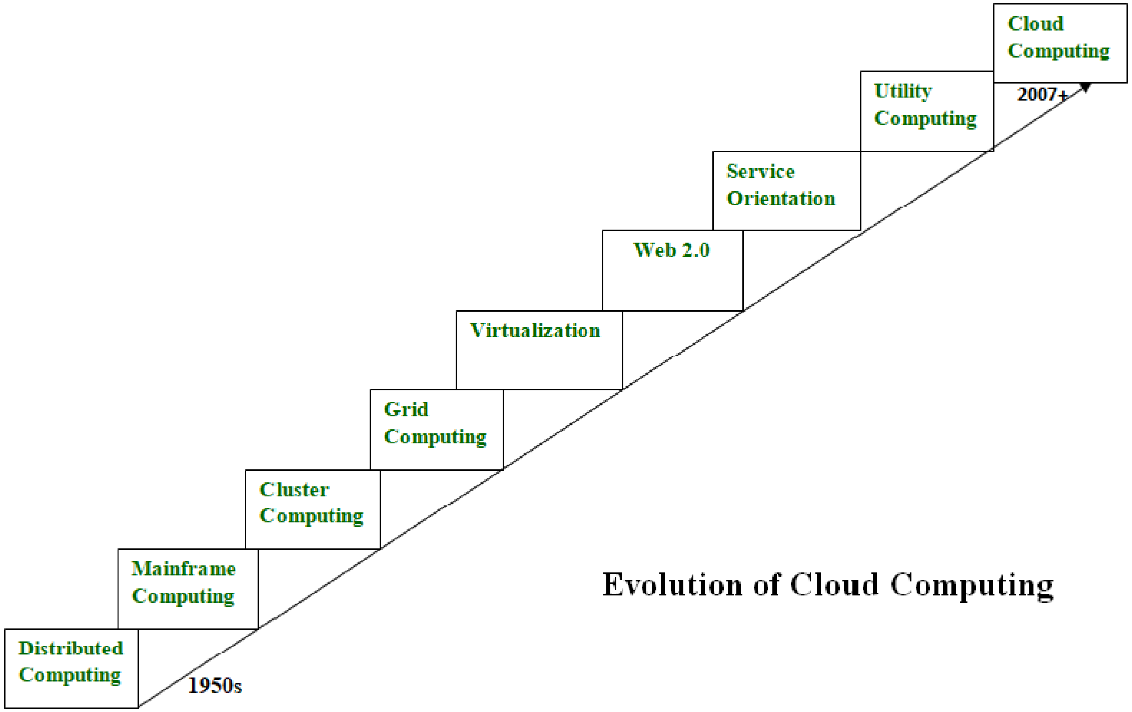
- **Network hardware**
  - One of the most important IT capabilities for data center to support remote IT access – broken down into five network subsystems in general
    - Carrier & external network interconnection ⇨ internetworking infrastructure comprised of backbone routers that provide routing between external WAN connections and LANs in the given data center including firewalls and VPN gateways
    - Web-tier load balancing and acceleration ⇨ for even distribution of web traffics and acceleration of web protocols comprised of XML pre-processors, encryption/decryption appliances (web acceleration), layer 7 switching devices (content-aware load balancing), etc.
    - LAN fabric ⇨ intranetworking infrastructure comprised of multiple layer 4 or lower switching devices up to ~10G bandwidth providing several virtualization functions such as LAN segregation into VLANs, link aggregation, control routing between networks, load balancing, failover (redundant connectivity), etc.
    - SAN fabric ⇨ data networking infrastructure composed of multiple SAN switching devices based on data networking protocols such as Fibre Channel (FC), Fibre Channel over Ethernet (FCoE), Infiniband (IB), Internet Small Computer Systems Interface (iSCSI)
    - NAS gateway ⇨ Provides shared file access over a network.,shared file-transfer networking infrastructure composed of a number of NAS-based storage devices based on file-transfer protocols such as NFS and SMB/CIFS-common internet file system (Samba)

Data Center Technology

- Basically **redundant and/or fault-tolerant networking configurations for scalability and high availability**
- DWDM (Dense Wavelength Driven Multiplexing) devices for ultra high-speed networking and improved resiliency ⇨ in general for the purpose of high-speed real-time data replication between data centers

❑ **Other consideration**

- Technological obsolescence, heterogeneity, security, vast quantities of data and their backup, etc.



https://www.geeksforgeeks.org/evolution-of-cloud-computing/

Web Technology

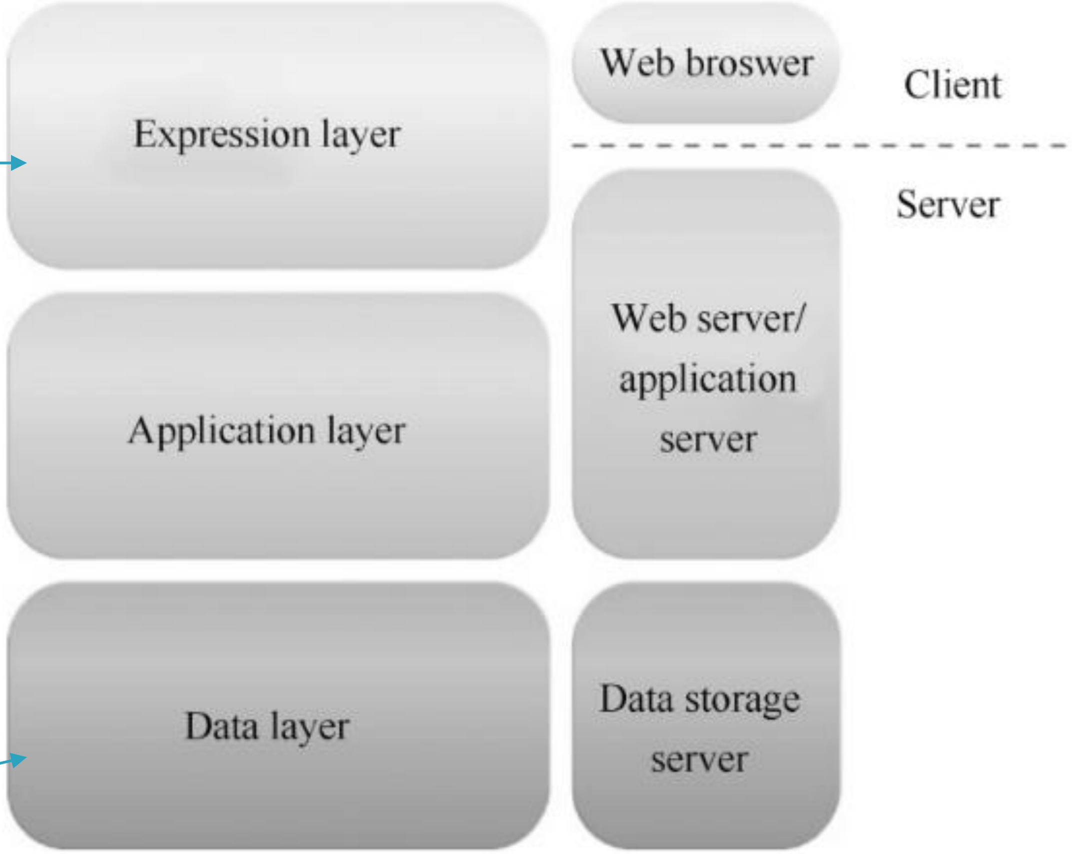
- Cloud computing has a deep-rooted dependence on the **Internet and Web technologies.**
- Uniform Resource Locator (URL): A standard syntax used to point to Web resources' identifier. URLs usually consist of logical network locations.
- HyperText Transfer Protocol (HTTP): The basic communication protocol for exchanging content and data through the World Wide Web. Usually, the URL is transmitted via HTTP.
- Markup Language-Hyper Text Markup Language (HTML) is commonly used in webpages
- Web application-

- A typical Web application may have a three-tier model, as shown in Fig.
- The first layer is the Presentation Layer, which is used to represent the user interface.
- The second layer is the Application Layer, which is used to implement application logic.
- The third layer is the Data Layer, which consists of persistent data storage.
- Known as the Model-View-Controller (MVC)

View

Controller

Model



The three-layer model of Web applications

- WORLD BEFORE WEB
  - Limited access to information
  - Limited communication options
  - Limited commerce
  - Limited entertainment options
  - Limited Job opportunities

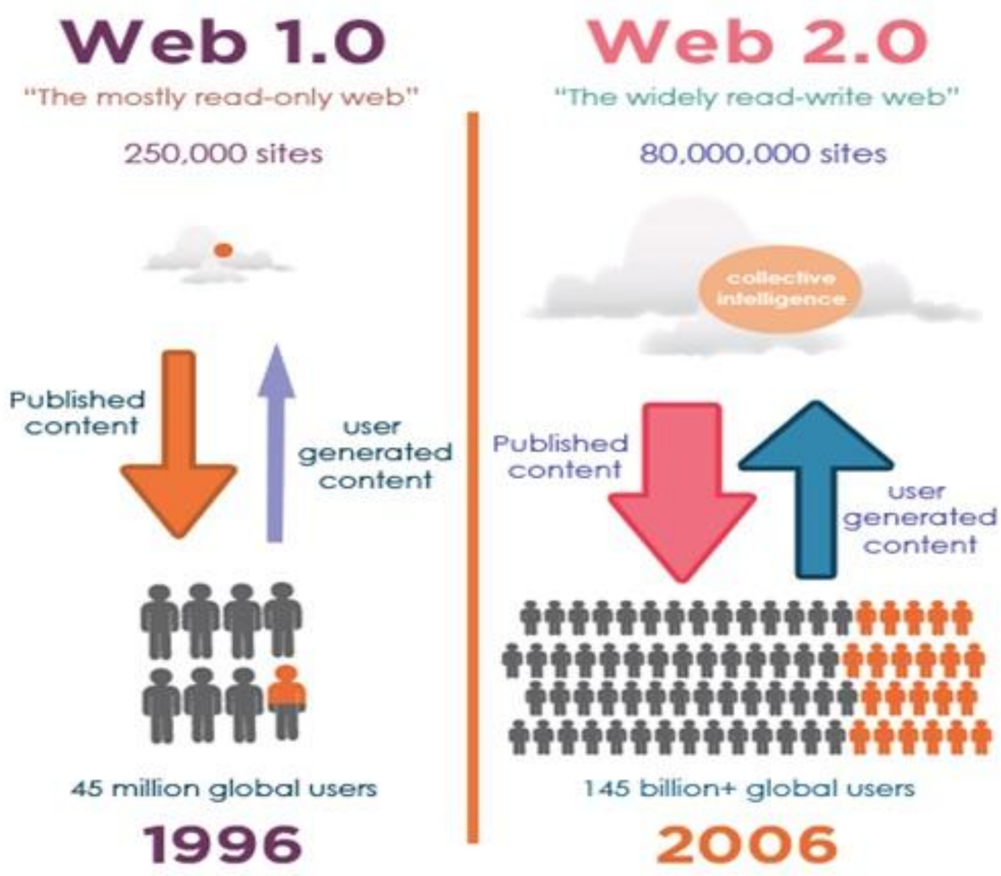
Web 1.0

- Web 1.0 (1990-2004), is a read-only web.
- Users were only the consumers of information; they can not provide any input.
- No or little interactions can be held on web 1.0.
- Lack of User-Generated Content

Web 2.0

- The web is the primary interface (medium) through which cloud computing delivers or provides its services to everyone.
- At present the Web encloses a troupe of technologies and services that facilitate interactive sharing, collaboration, user-centered design, and application composition.
- So basically Web 2.0 is the current state of online technology as it compares to early days of the Web, it comprises by **greater user interactivity and collaboration and enhanced communication channels.**
- The name Web 2.0 used to elaborate the second generation of www i.e. World Wide Web, where Web moved towards static HTML pages for more responsive and interactive as well as dynamic web experience.
- Web 2.0 is focused on the ability for user or people to **collaborate and share information online via social media**, web based communities, blogging and internet of course.
- But now for Web social media is a major component, new web applications such as AZAX and more modern browser providing opportunities for people to express their views.

Web 2.0



Web 1.0
"The mostly read-only web"
250,000 sites
Published content
user generated content
45 million global users
1996
Web 2.0
"The widely read-write web"
80,000,000 sites
collective intelligence
Published content
user generated content
145 billion+ global users
2006

Web 2.0


WEB 2.0
The era we live in today
Webmaster
Internet Surfers
Contributer
WEBSITE
RSS
User
User

Benefits of Web 2.0

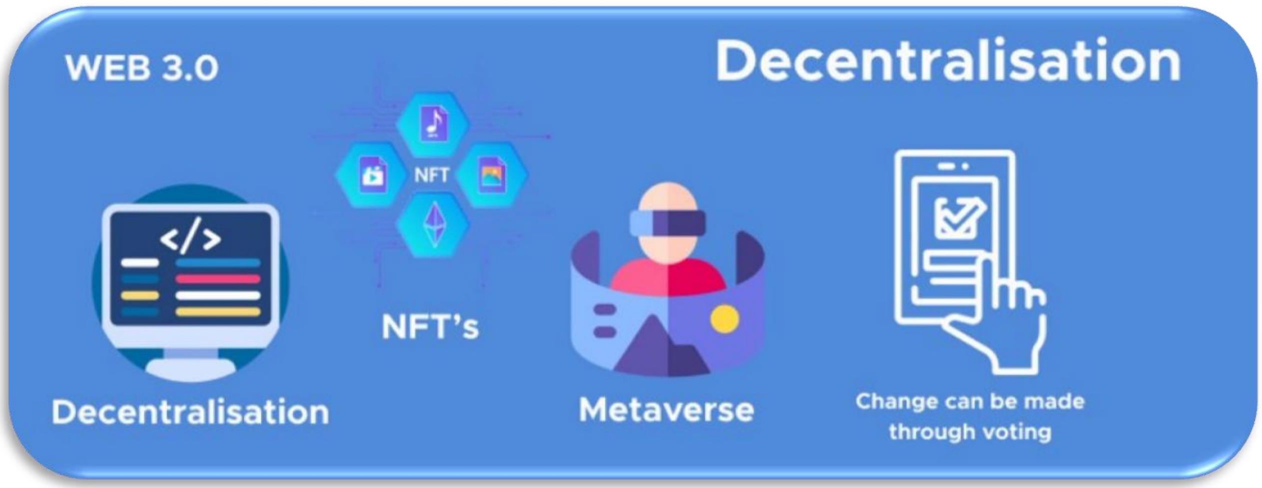
- We can access all the services available at internet anytime or from anywhere.
- Today's web services are user friendly or has better user interface.
- Multiple kind or different type of media is available on web.
- It can build a dynamic learning communities.
- Anyone can have real time discussion now.
- Everybody is an author and an editor now, every thing or every changes are traceable now.
- Learners can actively be involved in knowledge building.
- Success for search results are efficient.
- Updates of any information is easy.
- Web 2.0 is speedy, collaborative, trustworthy etc.

Service running on web 2.0

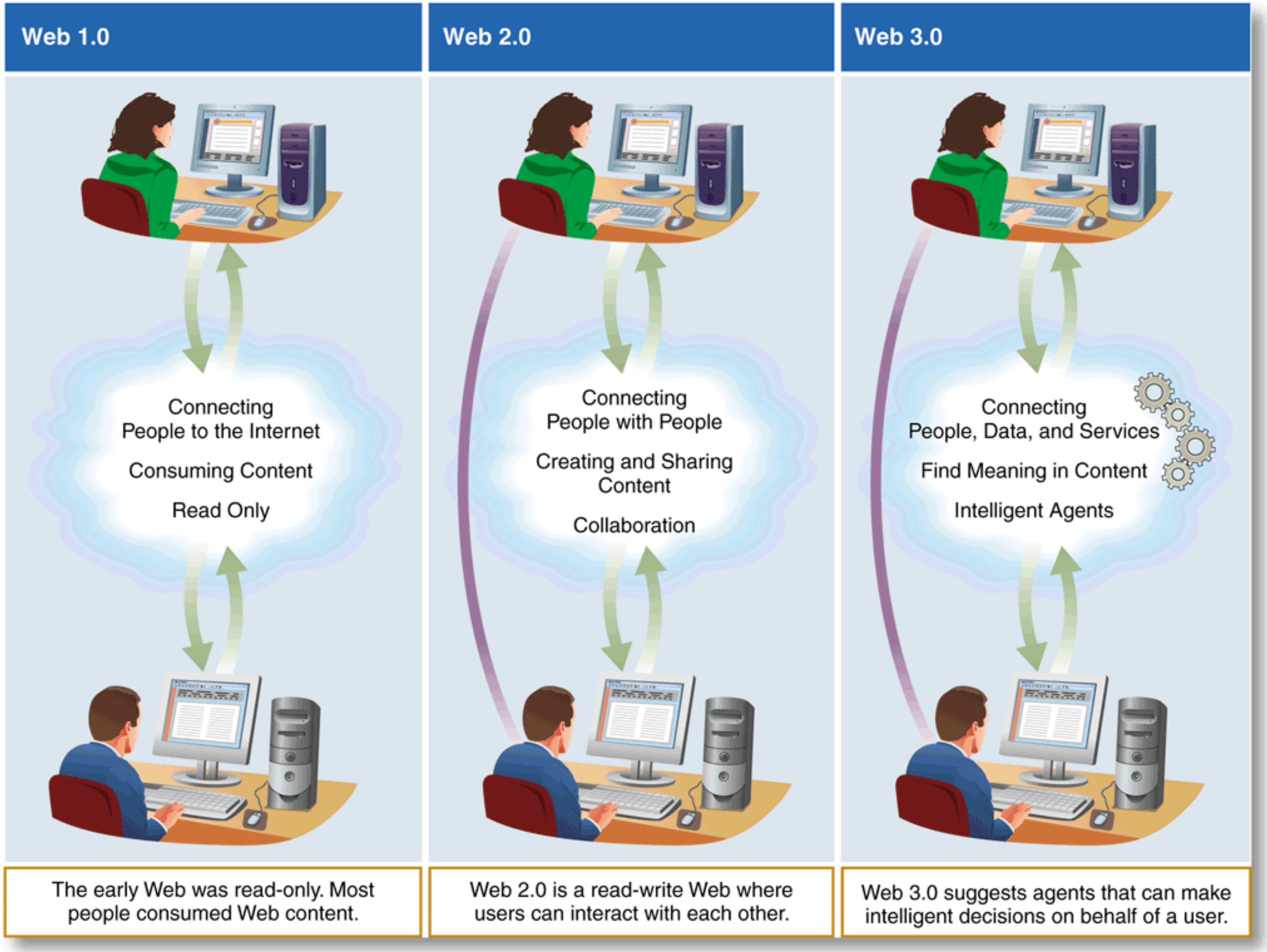
- Facebook
- Flicker
- Linked in
- YouTube
- Wikipedia
- BlogSpot
- Word press
- Twitter
- Pinterest
- Google Docs
- Instagram and many more.
- **Today every service available on internet is under Web 2.0.**

- Web 2.0 has a few other features and techniques, known as SLATES,
- SLATES stands for
  - Search- via keyword search
  - Links to other websites- connecting information sources
  - Authoring collaboration
  - Tags- categorization of information
  - Extensions- Adobe Reader, QuickTime, and Windows Media
  - Signals- the use of extension technology, such as an RSS feed

Web3.0


WEB 3.0
Decentralisation
NFT
NFT's
Decentralisation
Metaverse
Change can be made
through voting

What Makes Web 3.0 So Unique?
Artificial Intelligence
Computers now can understand information like a human being with the ability of natural language processing
Semantic Web
Better understands contents web rather than focusing on keywords and numeric values
Ubiquity
Every device will be connected to the network. Contents can be accessible by various applications
Web 3.0
3D Graphics
Utilizing Virtual Reality, more realistic and natural looking graphics are extensively used
Enhanced Connectivity
Web 3.0 uses semantic metadata to provide users better connectivity
Peer-to-Peer Network
A decentralized network that dissolves the need for a centralized authority
101 Blockchains
Created by 101blockchains.com


Web 1.0
Web 2.0
Web 3.0
Connecting
People to the Internet
Consuming Content
Read Only
Connecting
People with People
Creating and Sharing
Content
Collaboration
Connecting
People, Data, and Services
Find Meaning in Content
Intelligent Agents
The early Web was read-only. Most people consumed Web content.
Web 2.0 is a read-write Web where users can interact with each other.
Web 3.0 suggests agents that can make intelligent decisions on behalf of a user.

Comparison

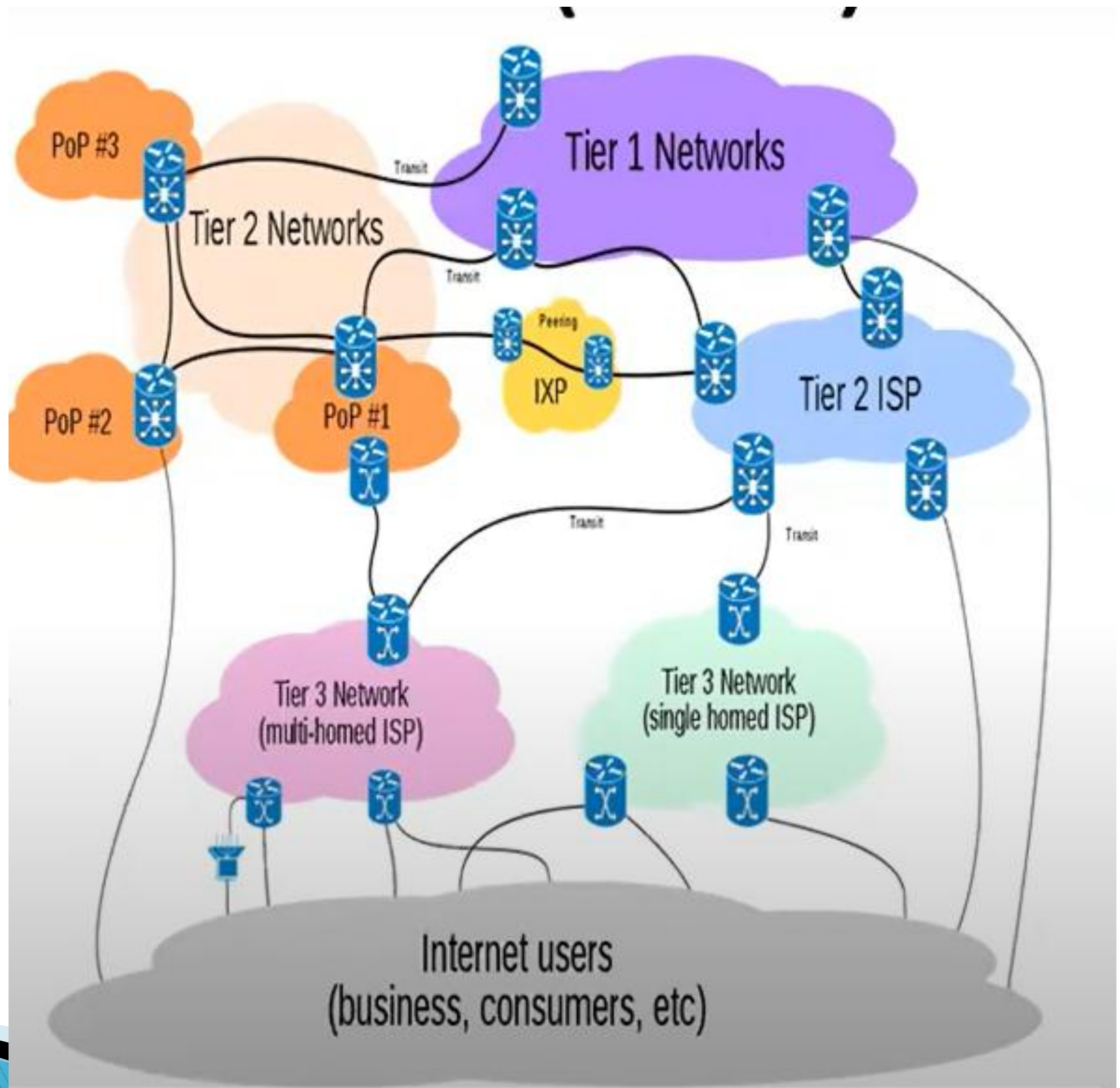
Web 1.0	Web 2.0	Web 3.0
Mostly Read-Only	Wildly Read-Write	Portable and Personal
Company Focus	Community Focus	Individual Focus
Home Pages	Blogs / Wikis	Live-streams / Waves
Owning Content	Sharing Content	Consolidating Content
Web Forms	Web Applications	Smart Applications
Directories	Tagging	User Behaviour
Page Views	Cost Per Click	User Engagement
Banner Advertising	Interactive Advertising	Behavioural Advertising
Britannica Online	Wikipedia	The Semantic web
HTML/Portals	XML / RSS	RDF-(Resource Description Framework) / RDFS / OWL-Web Ontology Language

Broadband Networks & Internet Architecture

- All clouds must connected to Internet
- **Cloud service**
  - Requires remotely accessible service by definition – network connections are inevitable
  - Implies inherent dependency on internet technology
  - Enables remote provisioning of IT resources via ubiquitous network access (VPN or public network)
  - Advances in accordance with the advancements of internet technology and QoS

Broadband Networks & Internet Architecture

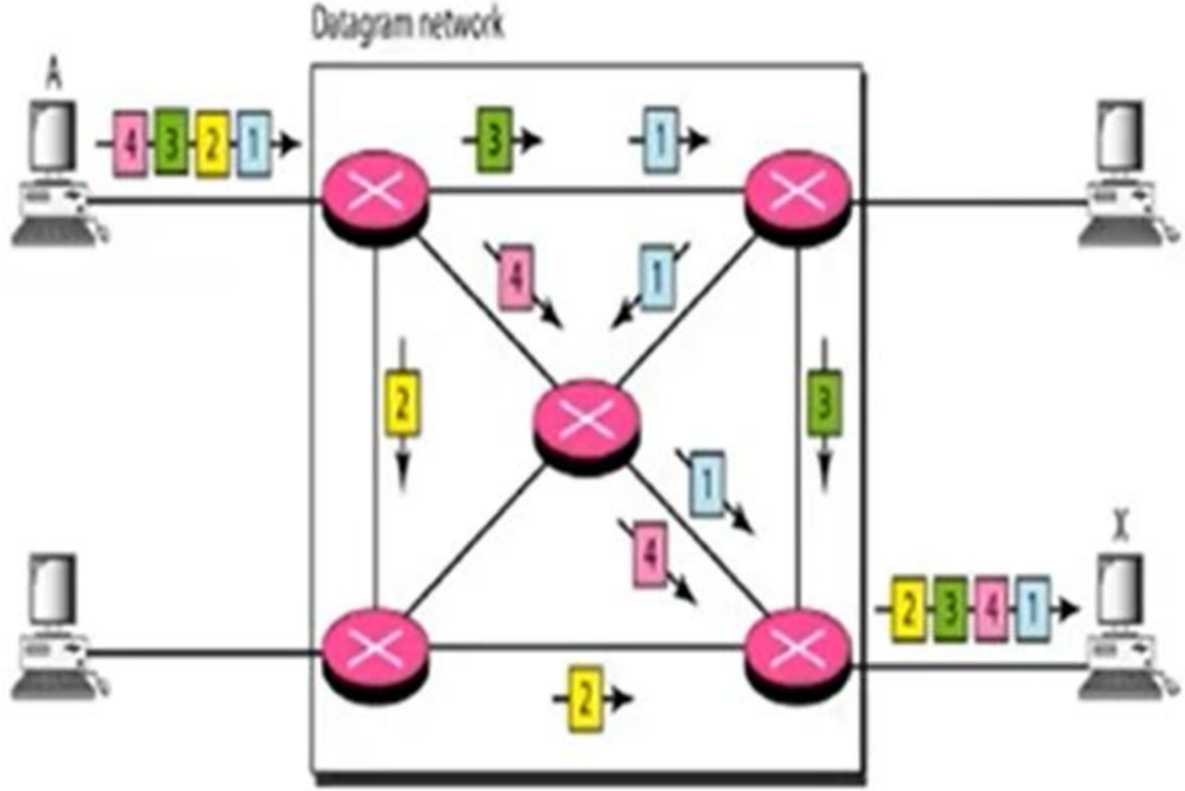
- **Internet Service Providers (ISPs)**
  - An organization providing national-wide or world-wide internet access service
  - Governed by Internet Corporations for Assigned Names and Numbers (ICANN)- responsible for coordinating the global Domain Name System (DNS) and IP address allocation, ensuring unique identifiers on the internet.
  - No comprehensive governing by ICANN – ISPs freely deploys, operates and manages their own networks based on basically decentralized provisioning and management models
  - Fundamental governmental and regulatory laws applied within national borders
  - **Internet topology** – a dynamic and complex aggregate of ISPs highly interconnected via its core protocols
  - Worldwide connectivity via a hierarchical topology composed of Tier 1(large-scale international ISPs), Tier 2 (large regional ISPs) and Tier 3 (local ISPs)
    - Communication links,routers of internet and IPS networks are IT resources
    - Two fundamental components of internetworking architecture**: connectionless packet switching(datagram network) vs. router-based interconnectivity**



Tier 1 Networks
PoP #3
Transit
Tier 2 Networks
Transit
Peering
IXP
PoP #2
PoP #1
Tier 2 ISP
Transit
Transit
Tier 3 Network
(multi-homed ISP)
Tier 3 Network
(single homed ISP)
Internet users
(business, consumers, etc)

Broadband Networks & Internet Architecture

- **Connectionless packet switching (datagram network)**
  - End-to-end (sender-receiver pair) data message divided into packets of limited size
  - Each packet processed through network switches and routers, queued and forwarded from one intermediary node to the next
  - Necessary transfer information carried by each packet in accordance with corresponding protocols such as Internet Protocol (**IP**) address or Media Access Control (**MAC**) address identifying devices on a local network


Datagram network
A
4
3
2
1
3
1
4
1
2
3
1
4
2
X
2
3
4
1

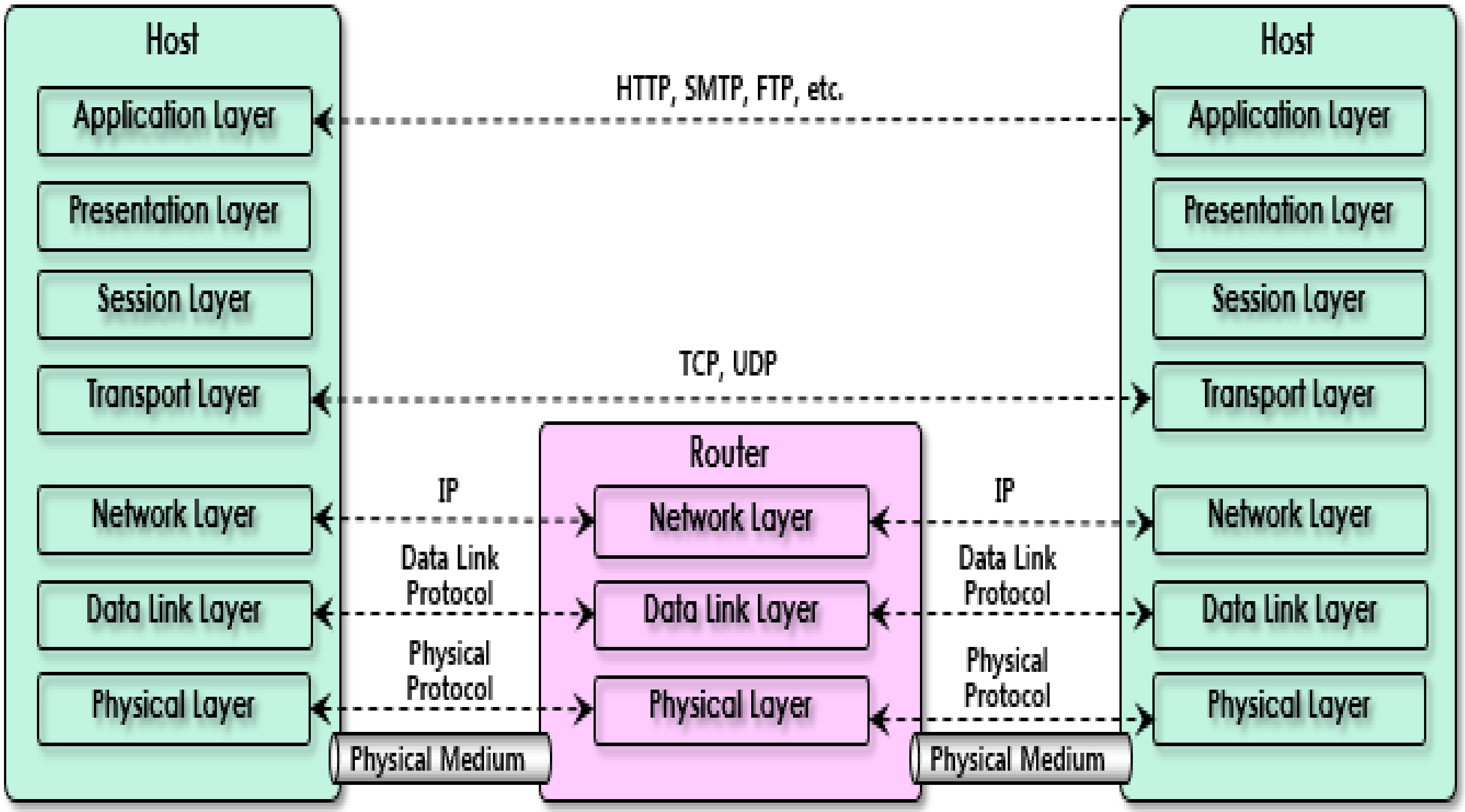
Broadband Networks & Internet Architecture

- **Router-based interconnectivity**
  - A router – a device connected to multiple networks through which it forwards packets
  - Each packet transferred (stored & forwarded at each router) to destination individually via possibly different routes from each other ⇨ routing information (IP addresses of the source & the destination, sequential number, etc.) included in each packet
  - Packets reassembled into a message on the destination node (at the network layer)
  - Each router responsible for finding the most efficient hop for packet delivery at runtime
  - Possibly multiple ISP networks between a cloud customer and its cloud provider
  - 7 abstraction layer model defined in **OSI** (Open Systems Interconnection) project by **ISO/IEC 7498-1**
    - physical layer (1), data link layer (2), network layer (3), transport layer (4), session layer (5), presentation layer (6), application layer (7)

Broadband Networks & Internet Architecture

Layer	Protocol Data Unit (PDU)	Function
7. Application	Data	High-level APIs, including resource sharing, remote file access – HTTP, FTP etc.
6. Presentation		Translation of data between a networking service and an application; including character encoding, data compression and encryption/decryption
5. Session		Managing communication sessions, i.e. continuous exchange of information in the form of multiple back-and-forth transmissions between two nodes
4. Transport	Segment (TPC) / Datagram (UDP)	Reliable transmission of data segments between points on a network, including segmentation, acknowledgement and multiplexing
3. Network	Packet	Handles routing and addressing, ensuring packets are sent to the correct destination (e.g., IP addresses).
2. Data Link	Frame	Reliable transmission of data frames between two nodes connected by a physical layer
1. Physical	Bit	Transmission and reception of raw bit streams over a physical medium cables, radio waves, or other media (e.g., Ethernet cables, fiber optics).

Broadband Networks & Internet Architecture



Broadband Networks & Internet Architecture

- **OSI 7 layer model**
  - Physical layer (Layer 1)
    - Defines for the electrical and physical specifications of the data connection
    - Defines the relationship between a device and a physical transmission medium (e.g., a copper or fiber optical cable, radio frequency) including the layout of pins, voltages, line impedance, cable specifications, signal timing and similar characteristics for connected devices and frequency (5 GHz or 2.4 GHz etc.) for wireless devices
    - Responsible for transmission and reception of unstructured raw data in a physical medium
    - Defines the network topology as bus, mesh, or ring being some of the most common
    - Includes **Parallel SCSI**, **Ethernet** & other local-area networks such as **token ring**, **FDDI**, **ITU-T G.hn**, and **IEEE 802.11** (Wi-Fi)
    - Defines personal area networks such as **Bluetooth** and **IEEE 802.15.4** as well
    - Defines low-level networking equipment, such as network adapters, repeaters, network hubs, modems, and fiber media converters
    - Protocol independent - never concerned with protocols or other such higher-layer items

Broadband Networks & Internet Architecture

- **OSI 7 layer model**
  - Data link layer (layer 2)
    - Provides node-to-node data transfer – a link between two directly connected nodes
    - Detects and possibly corrects errors that may occur in the physical layer
    - Defines the protocol to establish and terminate a connection between two physically connected devices as well as the protocol for flow control between them
    - High-speed local area networking over existing wires (power lines, phone lines and coaxial cables) defined by The **ITU-T G.hn** standard in this data link layer, providing both error correction and flow control by means of a selective-repeat sliding-window protocol

Broadband Networks & Internet Architecture

- **OSI 7 layer model**
  - Data link layer (layer 2)
    - Provides node-to-node data transfer – a link between two directly connected nodes
    - Detects and possibly corrects errors that may occur in the physical layer
    - Defines the protocol to establish and terminate a connection between two physically connected devices as well as the protocol for flow control between them
    - High-speed local area networking over existing wires (power lines, phone lines and coaxial cables) defined by The **ITU-T G.hn** standard in this data link layer, providing both error correction and flow control by means of a selective-repeat sliding-window protocol
    - Divided into two sublayers by IEEE 802:
      - **Media Access Control** (**MAC**) layer - responsible for controlling how devices in a network gain access to medium and permission to transmit it
      - **Logical Link Control** (**LLC**) layer - responsible for identifying Network layer protocols and then encapsulating them and controls error checking and frame synchronization
    - Includes the MAC and LLC layers of IEEE 802 networks such as **802.3 Ethernet**, **802.11 Wi-Fi**, and **802.15.4 ZigBee**
    - Defines the Point-to-Point Protocol (**PPP**) that can operate over several different physical layers, such as synchronous and asynchronous serial lines

Broadband Networks & Internet Architecture

- **OSI 7 layer model**
  - Network layer (Layer 3)
    - Provides the functional and procedural means of transferring variable length data sequences (called **datagrams**) from one node to another connected to the same "network"
    - A network – a communication medium to which many nodes with **addresses** (e.g., IP) can be connected, allowing each member node to transfer a message to any other member nodes via **address resolution** or **routing** through intermediate nodes
    - Large messages divided into several fragments before sending and reassembled again upon receiving at the network layer
    - May report delivery errors – message delivery at the network layer is not necessarily guaranteed to be reliable; a network layer protocol may provide reliable message delivery, but it need not do so.
    - Defines a number of layer-management protocols (a function defined in the *management annex*, ISO 7498/4) including routing protocols, multicast group management, network-layer information and error, and network-layer address assignment – determined by the payload that makes these belong to the network layer, not the protocol that carries them

Broadband Networks & Internet Architecture

- **OSI 7 layer model**
  - Transport layer (Layer 4)
    - Provides the functional and procedural means of transferring variable-length data sequences from a source to a destination host via one or more networks, while maintaining the quality of service functions - Transmission Control Protocol (TCP) usually built on top of the Internet Protocol (IP) is an example of a transport-layer protocol in the standard Internet stack
    - Controls the reliability of a given link through flow control, segmentation/desegmentation, and error control
    - Some protocols are state- and connection-oriented implying that the transport layer can keep track of the segments and re-transmit those that fail.
    - Also provides the acknowledgement of the successful data transmission and sends the next data if no errors occurred
    - Creates packets out of the message received from the application layer. Packetizing is a process of dividing the long message into smaller messages.
    - Five classes of connection-mode transport protocols defined by OSI, ranging from class 0 (which is also known as TP0 and provides the fewest features) to class 4 (TP4, designed for less reliable networks, similar to the Internet)
      - Class 0: contains no error recovery and designed for use on network layers that provide error-free connections
      - Class 4: closest to TCP, although TCP contains functions, such as the graceful close, which OSI assigns to the session layer
      - All OSI TP connection-mode protocol classes provide expedited data and preservation of record boundaries.
    - Similar to a post office which deals with the dispatch and classification of mail and parcels sent

Broadband Networks & Internet Architecture

- **OSI 7 layer model**
  - Packets are then encapsulated into higher level protocols, such as cryptographic presentation services that can be read by the addressee only.
  - Non-IP tunneling protocols operating at the transport layer: IBM's **SNA**, Novell's **IPX** over an IP network, or end-to-end encryption with **IPsec**
  - While Generic Routing Encapsulation (GRE) might seem to be a network-layer protocol, if the encapsulation of the payload takes place only at endpoint, GRE becomes closer to a transport protocol that uses IP headers but contains complete frames or packets to deliver to an endpoint.
  - L2TP carries PPP frames inside transport packet.
  - Although not developed under the OSI Reference Model and not strictly conforming to the OSI definition of the transport layer, the Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP) of the Internet Protocol Suite are commonly categorized as layer-4 protocols within OSI.

Broadband Networks & Internet Architecture

- **OSI 7 layer model**
  - Session layer (Layer 5)
    - Controls the dialogues (connections) between computers - establishing, managing and terminating the connections between the local and remote application
    - Provides for full-duplex, half-duplex, or simplex operation, and establishes checkpointing, adjournment, termination, and restart procedures
    - Also provides graceful close of sessions which is a property of the Transmission Control Protocol and session checkpointing and recovery which is not usually used in the Internet Protocol Suite
    - Commonly implemented explicitly in application environments that use remote procedure calls

Broadband Networks & Internet Architecture

- **OSI 7 layer model**
  - Presentation layer (Layer 6)
    - Establishes context between application-layer entities, in which the application-layer entities may use different syntax and semantics if the presentation service provides a mapping between them
    - Encapsulates presentation service data units into session protocol data units that are then passed down the protocol stack If a mapping is available
    - Provides independence from data representation (e.g., encryption) by translating between application and network formats
    - Transforms data into the form that the application accepts - formatting and encrypting data to be sent across a network (sometimes called the syntax layer)
    - The original presentation structure used the Basic Encoding Rules of Abstract Syntax Notation One (ASN.1) with capabilities such as converting an EBCDIC-coded text file to an ASCII-coded file, or serialization of objects and other data structures from and to XML.

Broadband Networks & Internet Architecture

- **OSI 7 layer model**
  - Application layer (Layer 7)
    - The OSI layer closest to the end user which means both the OSI application layer and the user interact directly with the software application
    - Interacts with software applications (outside the scope of the OSI model) that implement a communicating component
    - Includes functions such as identifying communication partners, determining resource availability, and synchronizing communication
    - Determines the identity and availability of communication partners for an application with data to transmit when identifying communication partners
    - Must decide whether sufficient network resources for the requested communication are available when determining resource availability

Broadband Networks & Internet Architecture

- **Technical and business considerations**
  - Connectivity issues
    - Traditional deployment model
      - Via the corporate network (VPN) which provide uninterrupted Internet connectivity
      - Completely controlled by the organizations with their own safeguard based on firewalls and various monitoring tools
      - Each organization responsible for deploying, operating and managing their IT resources and Internet connectivity
    - Cloud deployment model
      - Continuous access to centralized servers and applications granted to end-user devices as long as they are connected to the network through the Internet in the cloud
      - Centralized IT resources accessible using the same network protocols regardless of whether users reside inside or outside of a corporate network
      - Cloud IT resources configured by cloud providers to be accessible for both external and internal users through an Internet connection and for cloud consumers to provide Internet-based services to external users

Broadband Networks & Internet Architecture

On-premise IT Resources	Cloud-based IT Resources
Internal end-user devices access corporate IT services through the corporate network.	Internal end-user devices access corporate IT services through an Internet connection.
Internal users access corporate IT services through the corporate Internet connection while roaming in external networks.	Internal users access corporate IT services while roaming in external networks through the cloud provider's Internet connection.
External users access corporate IT services through the corporate Internet connection.	External users access corporate IT services through the cloud provider's Internet connection.

Broadband Networks & Internet Architecture

- Network bandwidth and latency issues
  - Network QoS: bandwidth, latency, jitter
  - **Bandwidth** – how much data can be transferred within a unit time, (**bps** Mbps, Gbps)
    - End-to-end bandwidth determined by the transmission capacity of the shared data links that connect intermediary nodes
    - Attempt to improve end-to-end bandwidth by ISPs with technologies such as broadband network technology & web acceleration technologies – dynamic caching, compression, pre-fetching, etc.
    - Critical for applications requiring substantial amount of data transfer

Broadband Networks & Internet Architecture

- Network bandwidth and latency issues
  - **Latency** – how fast a request can be satisfied (time for a packet to travel from one node to another), milliseconds (ms)
    - The longer a packet travels the larger the latency is – web caching technology can apply
    - The more network traffic is the larger the latency is – more queuing delay at each hop

Broadband Networks & Internet Architecture

- Network bandwidth and latency issues
  - **Jitter** – The variation in latency over time, caused by network congestion or route changes.
    - A gap between the smallest latency and the largest latency
    - Response time less than a millisecond in general, but frequently more than several seconds
    - Internet-wide QoS control required to guarantee small jitter
  - QoS of the underlying network inherited to QoS of the given cloud service

Broadband Networks & Internet Architecture

- Network bandwidth and latency issues
- Cloud carrier and cloud provider selection
  - Involves multiple cloud carriers to achieve the necessary level of connectivity and reliability for the given cloud applications resulting in additional costs
  - QoS determined by multiple ISPs involved & required collaboration of the cloud carriers
  - Wise to adopt more relaxed latency and bandwidth requirements