



Introduction to Network Planning and Design

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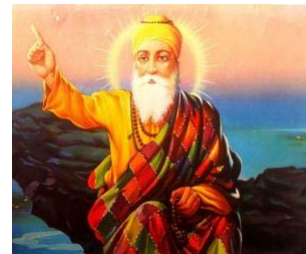
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In the Beginning...

- The design of a Network was the result of the inspiration of a guru or an "artist" (after all, it was considered almost an art ...)
- Technically the solution pointed to:
 - Traffic distribution pattern as 80/20
 - Whenever possible, all interconnections are done with bridges
 - If there were bottlenecks, delays or other problems then... increase the bandwidth!



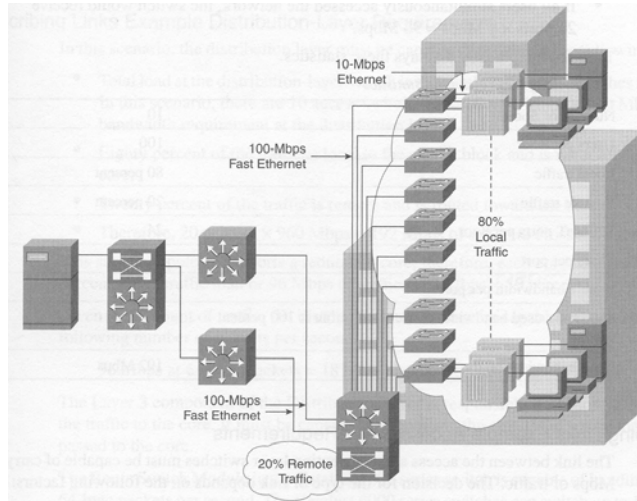
http://www.columbia.edu/itc/mealea/pritchett/00/routesdata/1500_1599/sikhism/gurus

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80/20



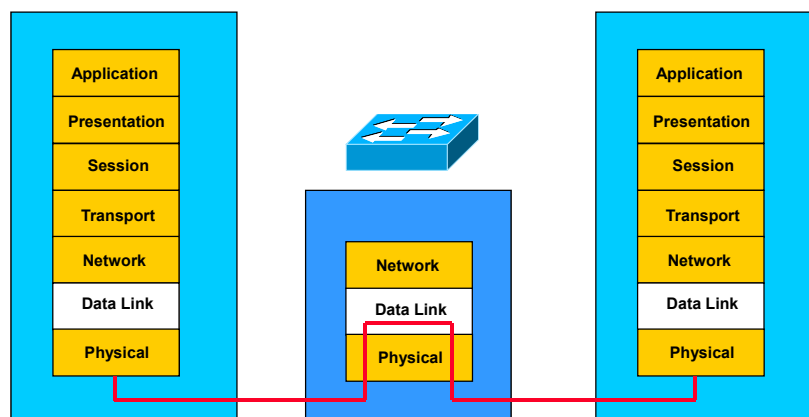
Traffic volume:
80% local
20% remote

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Interconnection at level 2



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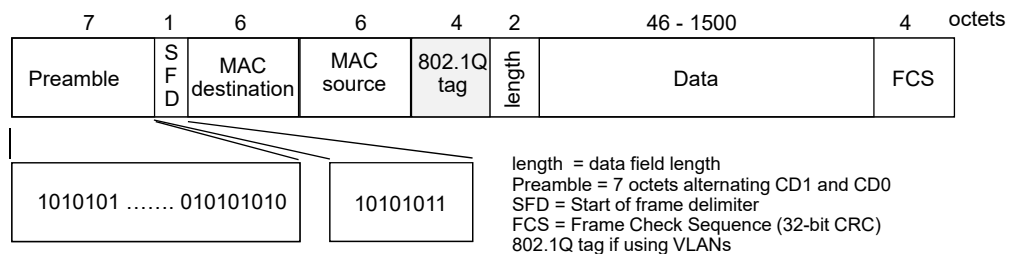


Interconnect at level 2

- The data link layer provides a link between two directly connected nodes
- Solutions for making segments interconnection
 - Repeaters/Hubs
 - Bridges
 - Switches
- Differences and implications?
- Interconnection between different physical layers?
- 802.1Q
- VLANs and broadcast domains?



Bridges, Frames and Errors

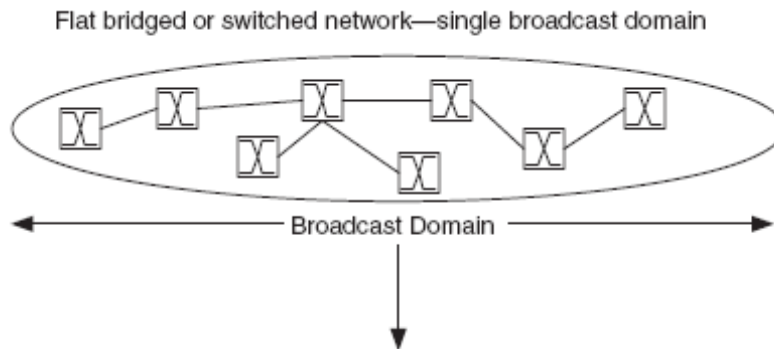


- ANSI/IEEE Std 802.1D - Media Access Control (MAC) Bridges
 - 6.3 Quality of service maintenance

"Note that the frame is completely received before it is relayed as the Frame Check Sequence (FCS) is to be calculated and the frame discarded if in error."



Flat hierarchy



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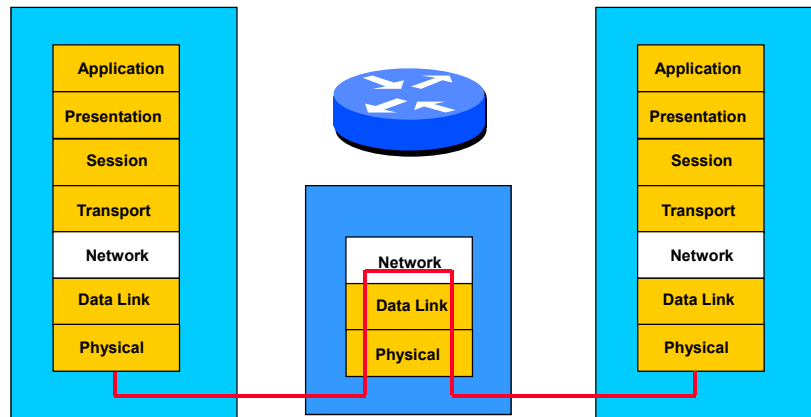
Interconnection using Bridges

- It is a low cost solution, compared with a router based interconnection
- Expand the LAN (limited by the round-trip delay)
- Isolates faulty segments, the hub/repeater can not do it
- Additional security: the stations only see the traffic that they need
- Problem with broadcast storms
- Simple configuration

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Interconnection using Routers



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Interconnection using Routers

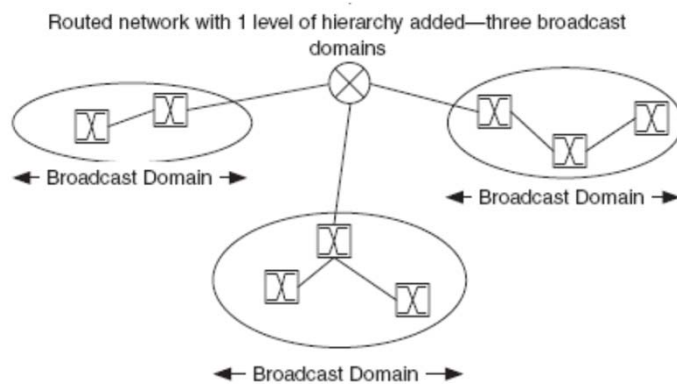
- More expensive solution
- Administratively isolates network parts
- Additional security: selective traffic routing
- Solves the broadcast storms problem
- Complex configuration

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Addition of a router



Step by step

- Requirements
- Planning previously the Design
- Typically planning is done by capacity...
- Problems?

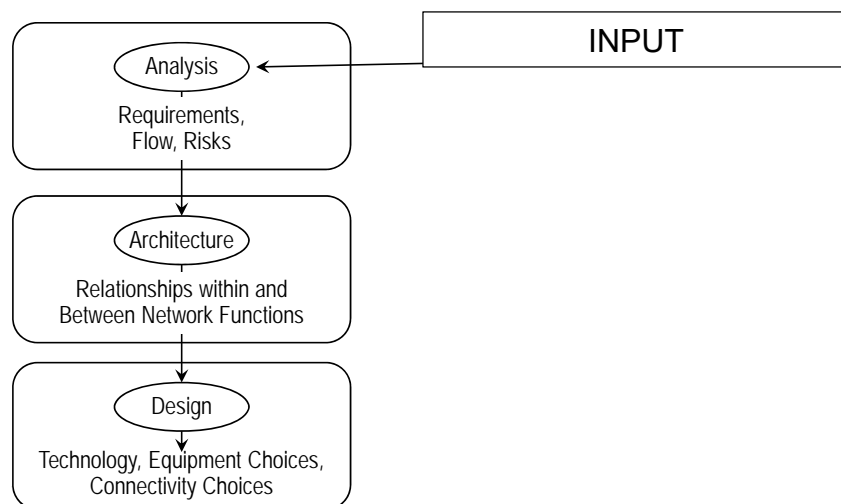


Capacity Planning

- Anticipate network capacity to withstand fluctuations in the short or long term traffic
- Traditionally is synonymous to anticipate the bandwidth required to support the different variations of traffic
- Nowadays it is clear the importance of non-functional requirements:
 - It is clear that it is also necessary to control the delay, network reliability, availability, maintainability (RMA)

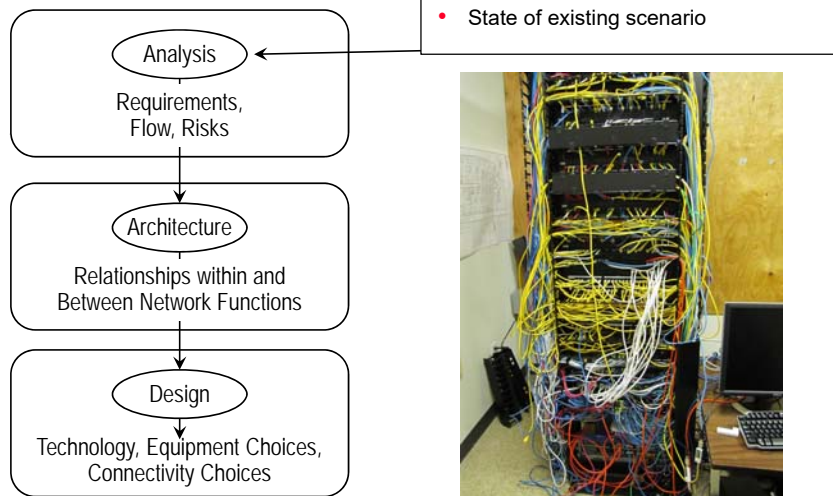


Requirements Analysis





Requirements Analysis

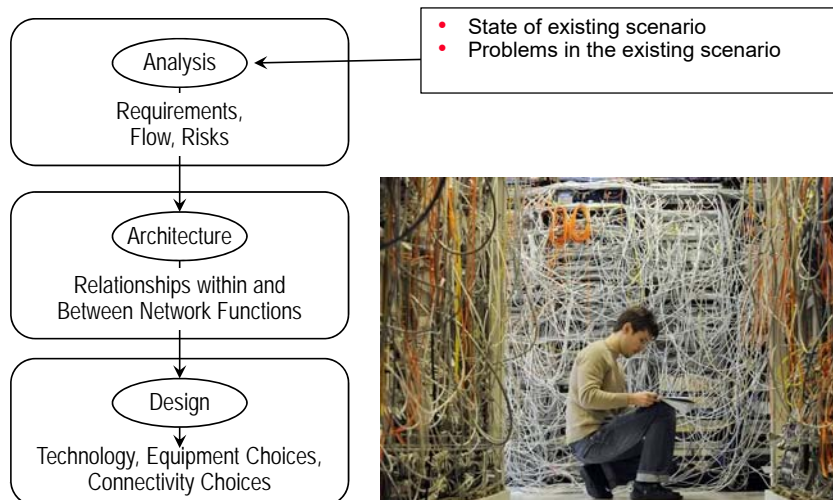


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Requirements Analysis

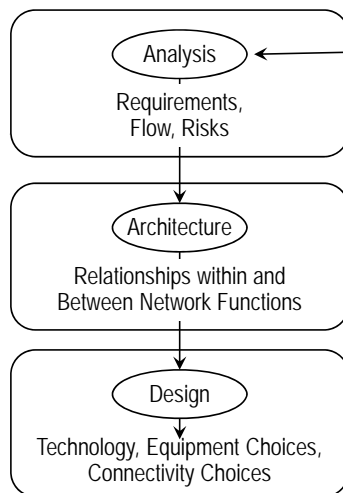


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Requirements Analysis



- State of existing scenario
- Problems in the existing scenario
- Project goals

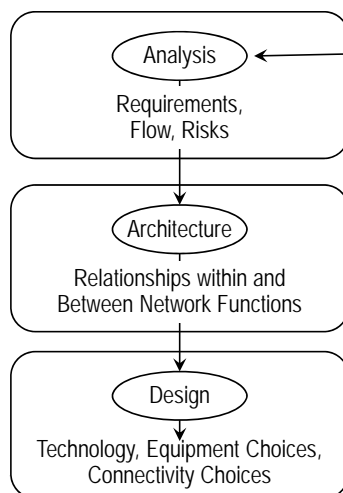


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Requirements Analysis



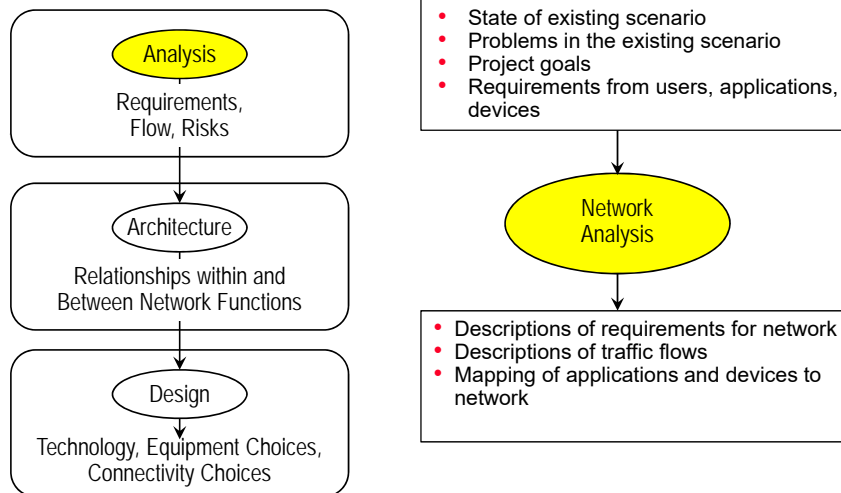
- State of existing scenario
- Problems in the existing scenario
- Project goals
- Requirements from users, applications, devices

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Requirements Analysis

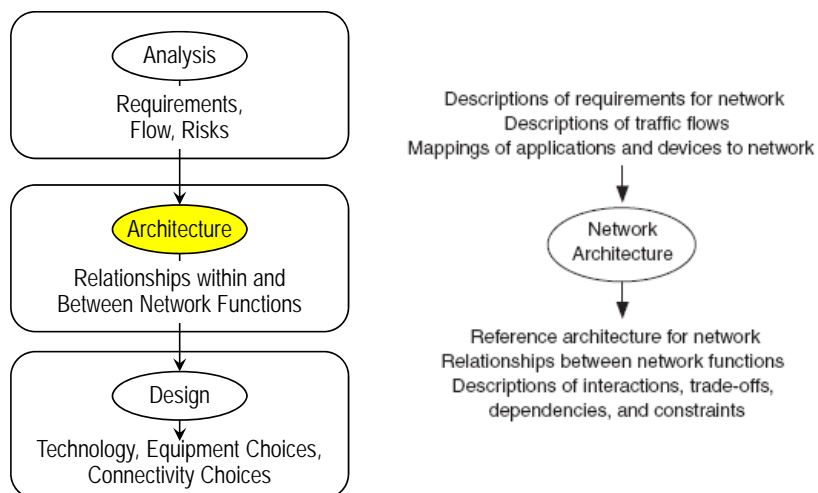


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Flow of information

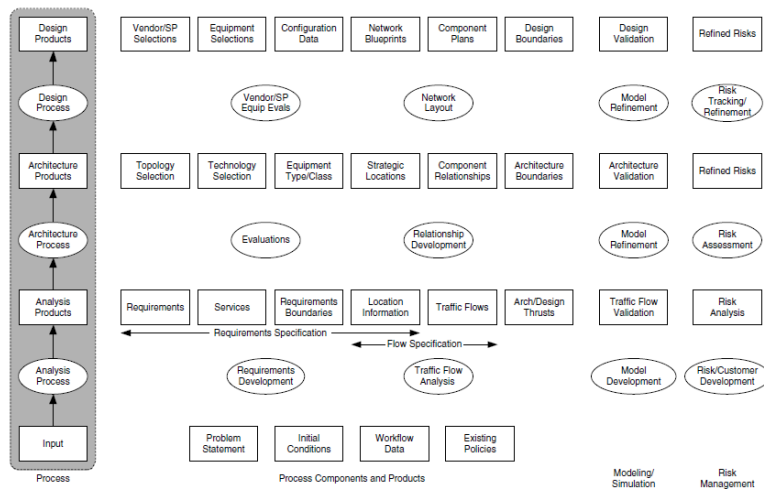


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Complete Process

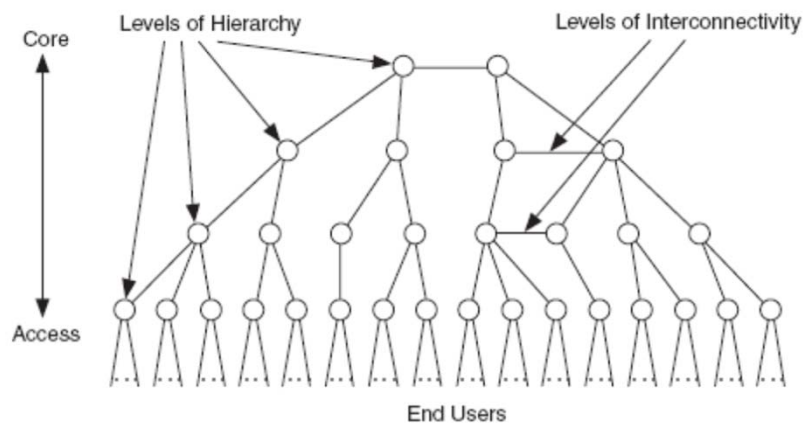


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Hierarchy and Interconnectivity

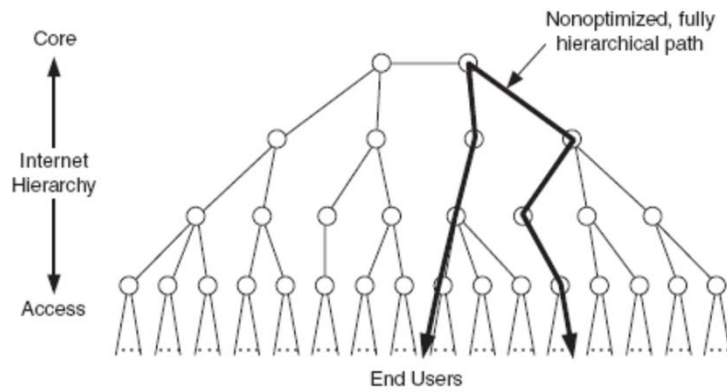


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Hierarchy and traffic flow

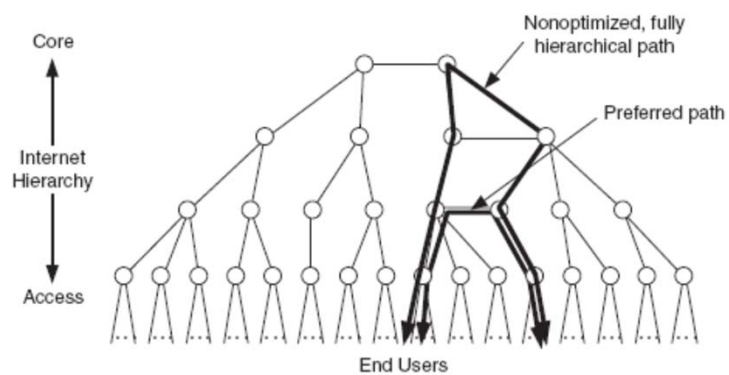


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Interconnectivity

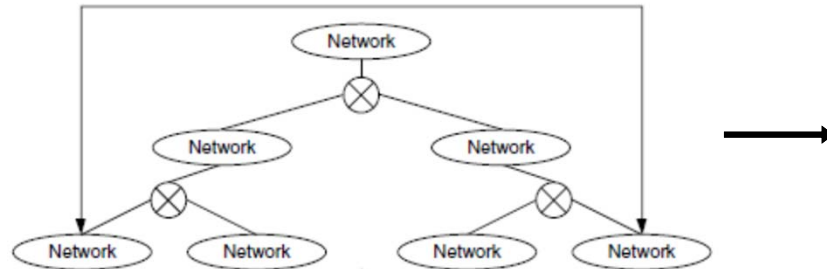


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Hierarchical structure of the network



- Hierarchical network: flows are forced through hierarchy, impacting performance

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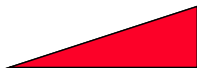
Content Delivery Network

- Content Delivery Network or Content Distribution Network (CDN)
- Servers containing copies of data, are placed at various points in a network so as to maximize bandwidth for access to the data from clients throughout the network
- The connections of end-users are served by CDN edges instead of the content source, e.g. Akamai



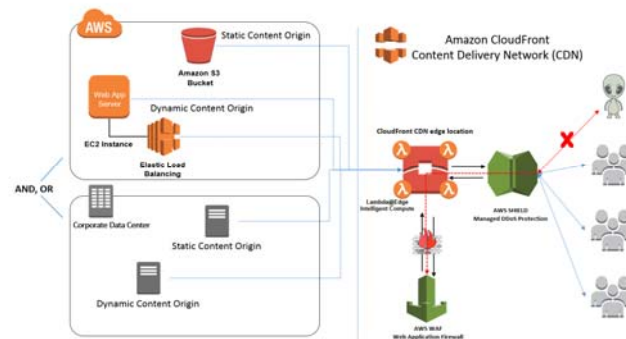
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Content Delivery Network

- A CDN bypasses the core of a network, where congestion is most likely to occur, and directly connects devices or networks lower in the hierarchy
- CDN predictably improves network performance but introduces potential routing problems

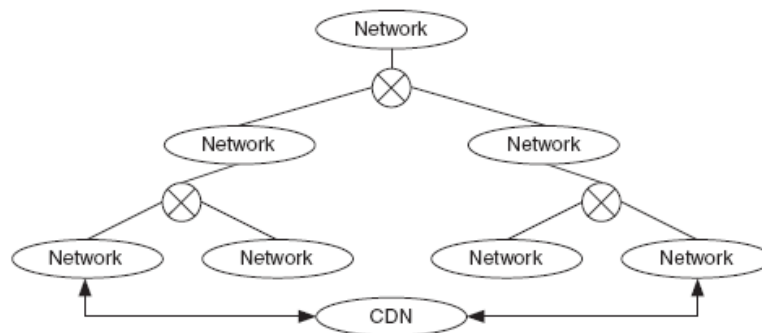


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Content Delivery Network



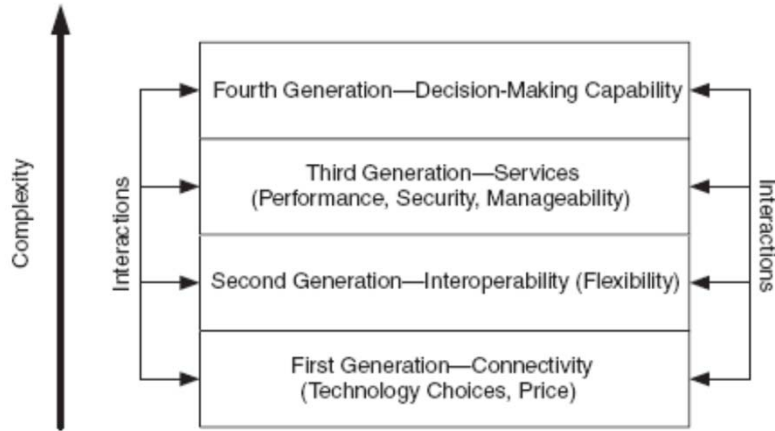
CDN is added, providing direct connectivity between networks, bypassing hierarchy and providing better performance

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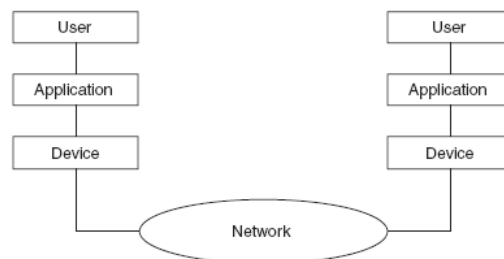
Generations of Networking



Through evolution, the networks are now based on services ...



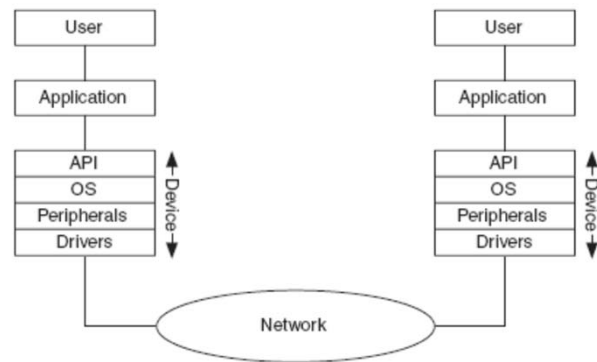
System Components



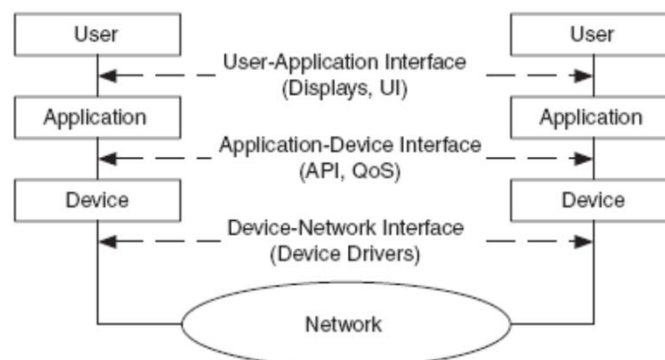
The generic components of a system are: the user, the application, the equipment (computer, peripheral, etc. ...) and the network



Details of Equipment

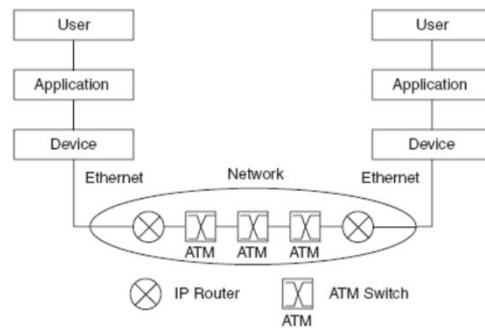


System Interfaces





Network Component Example

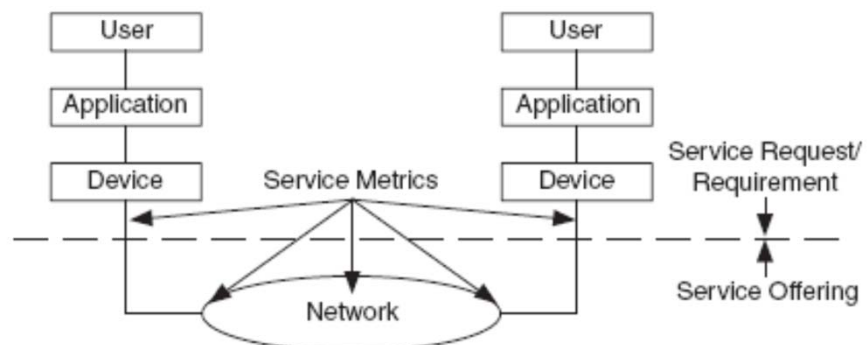


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System Components and Service Level



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Service Characteristics

- *Service characteristics* are individual network performance and functional parameters that are used to describe services
- Services are offered by the network to the system (the *service offering*) or are requested from the network by users, applications, or devices (the *service request*)
- Characteristics of services that are requested from the network can also be considered requirements for that network



Service Levels

- Service characteristics can be grouped together to form one or more *service levels* for the network;
- Service levels make provisioning easier in that you can configure, manage, account, and bill for a group of service characteristics (service level) instead of a number of individual characteristics;
- For example, a service level (e.g., gold) may combine capacity (e.g., 100 Mb/s) and reliability (as 99.99 % uptime)

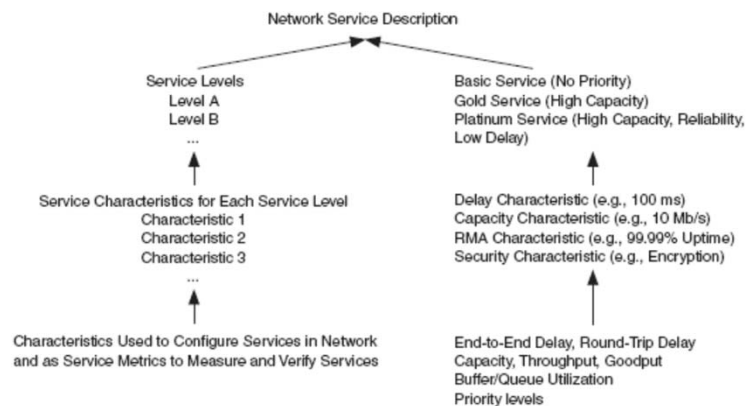


Service Level

- Examples of description of service levels:
 - Frame Relay Committed Information Rates (CIR)
 - ATM Class of Service (CoS)
 - IP Type of Service (ToS)
 - IP Quality of Service (QoS)



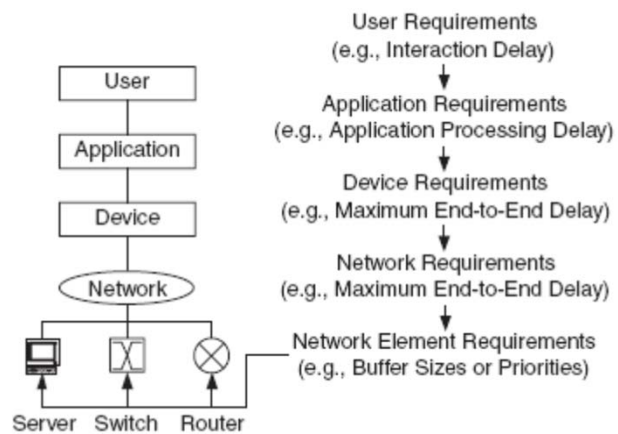
Network Services



RMA - Reliability, Maintainability and Availability



System Components and Service Level

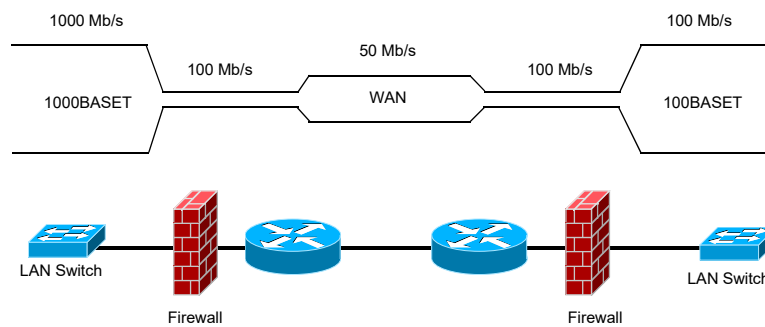


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Performance Problems

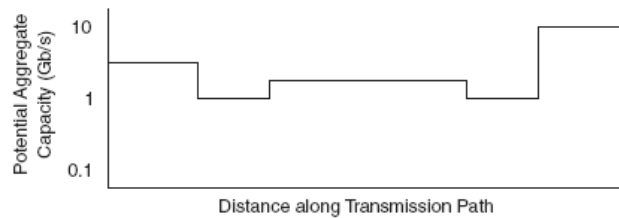


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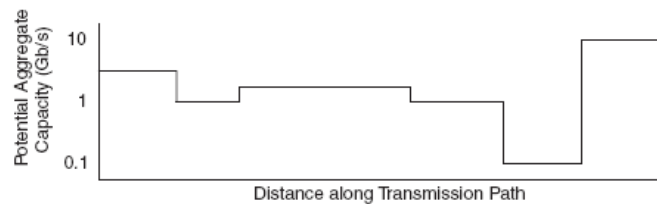
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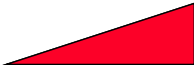


Before the Firewall



With Firewall





Service Request

- Service requests and requirements are, in part, distinguished by the degree of predictability needed from the service by the user, application, or device making the request
- Service categories:
 - **Best-effort** - there is no control over how the network will satisfy the service request;
 - **Predictable** - require some degree of predictability (more than best effort) yet do not require the accountability of a guaranteed service;
 - **Guaranteed** - must be predictable and reliable (implies a contract between the user and provider).

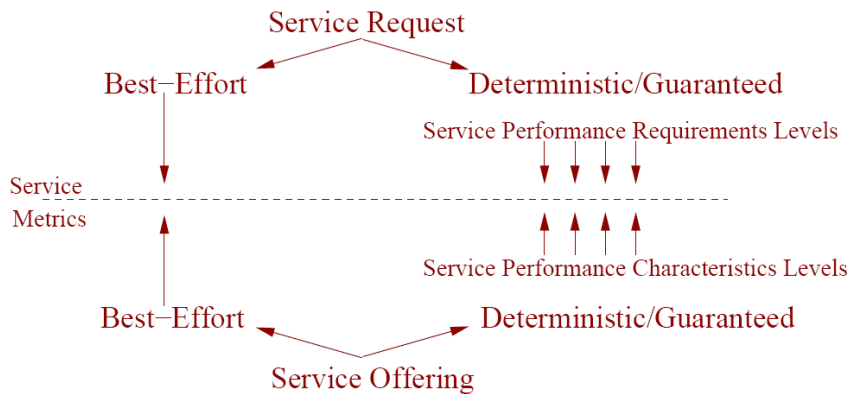


Service Offerings

- Service Offerings are the network counterparts to user, application, and device Requests for Service
- As Service Requests, Service Offerings can be categorized as *best-effort*, *predictable*, or *guaranteed*.
- *Predictable* and *guaranteed* service offerings implies that has to be some knowledge of the network, along with control over the network.



Requirements and services offering



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Service Metrics

- For service performance requirements and characteristics to be useful, they must be configurable, measurable, and verifiable;
- Therefore, it is reasonable to describe performance requirements and characteristics in terms of *service metrics*;
- *Service metrics* are meant to be configurable and measurable quantities, and so they can be used to measure thresholds and limits of service.

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Performance Requirements

- *Reliability*
- *Maintainability*
- *Availability*
- *Capacity*
- *Delay*



Performance Requirements

- *Reliability* – is a measure of the frequency of failure of the system and represents the unscheduled outages of service;
- *Maintainability*
- *Availability*
- *Capacity*
- *Delay*



Performance Requirements

- *Reliability*
- *Maintainability* – is a measure of the time to restore the system to fully operational status after it has experienced a fault;
- *Availability*
- *Capacity*
- *Delay*



Performance Requirements

- *Reliability*
- *Maintainability*
- *Availability* – defined as the probability that the system is operating properly when it is requested;

$$A = (MTBF) / (MTBF + MTTR)$$

- *Capacity*
- *Delay*



Performance Requirements

- *Reliability*
- *Maintainability*
- *Availability*
- *Capacity* – is a measure of information (voice, data, video, or a mix of these) carrying capacity of the system: *bandwidth, throughput, or goodput*,
- *Delay*



Performance Requirements

- *Reliability*
- *Maintainability*
- *Availability*
- *Capacity*
- *Delay* – is a measure of the difference of time in information transmission through the system.



Bibliography



- **McCabe, James D.**
Network Analysis, Architecture and Design
3rd Ed., The Morgan Kaufmann Series in Networking (2007)
ISBN 978-0-12-370480-1

Chapters 1 - 2