Network design & notes on network simulations

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Goal of this lecture

- Give an overall view of network planning process and procedures
- Serve as background information to the exercise of this course
- After this lecture you should
  - Be able to describe different parts of network planning and design
  - Be able to critically assess the pros and cons of network simulations
    - Additional (mandatory) reading provided in the course homepages

Network planning

- In the current Internet service provider (ISP) environment, service-level agreements (SLA) require that IP-based services provide quality of service (QoS) guarantees.
- Networks should be planned
  - to utilize network resources as efficiently as possible
  - to maximize the revenue of the operator
  - to maximize the user perceived QoS
- Network planning should be an ongoing process

Sensible design principles for new networks and services

1. The analysis of **customer needs** has to concentrate on practical uses that are likely to become everyday routines.
2. The **development of a new technology** must be based on well–defined, carefully selected core principles.
   - Simplicity and realism, BTW
3. During the development process the **real experiences in real networks** must be continuously taken into account.

- Please, read http://www.firstmonday.org/issues/issue10_1/kilkki/

Before starting…

- Who are your clients?
- Where are your clients? (mobility, VPNs)
- What do they need (as far as networking needs go)?
  - How do you know the answers?
- What are the services provided in the network and to whom are they provided?

Network design

- Before designing the (physical) network, determine your needs.
  - What services will you provide ?
  - What are the resources you'll need?
    - Equipment, personnel, software, premises etc.
  - You can't please all of the users all of the time, only some of the users some of the time
    - What will it take to satisfy the most users or to provide the more important services?
  - Choosing the network protocols, applications, network speed and dealing with network security issues.
  - Do not forget the budget. €£$
- When you start, remember to check whether you are building a network from the scratch or upgrading an existing one

Schedule for Availability

- Server clusters
- Redundancy links, redundant topologies
  - Plan for survivability (see the resiliency-lecture)
- Maintenance breaks
- Upgrade breaks
- Unexpected breaks
  - Faults, power outages, etc.

Step I: Networking needs & goals

- Business goals
  - Increase of revenue, market share
  - Offer new services, use new technologies
- Business constraints
  - Budgetary constraints
  - Staff constraints
- Technical goals
  - Scalability, availability (five 9s), network performance, utilization, throughput, QoS, security
  - Tradeoff list
- Assessing existing infrastructure
  - Devices, performance, unused potential, inefficienies, bottlenecks
- Network traffic characterization
  - User&usage profiles, application profiles, traffic policies
- Security issues
  - Access restrictions, application restrictions, are users trusted and to what extent

Step II: Cost analysis

- Performed at the start of the operator business
  - Equipment costs, Labor costs, Carrier fees
    - Initial/Installation costs
    - Ongoing costs
- Multiyear analysis
  - helps to determine when business becomes profitable
  - determine the pricing level and logic

Step III: Logical network design

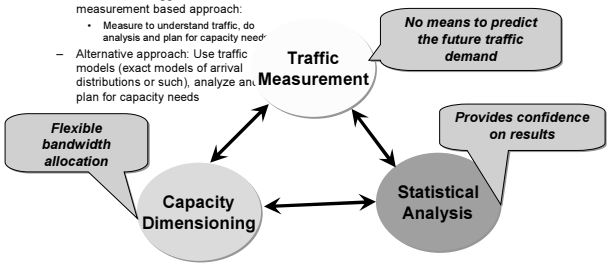
- Topology design (for fault tolerance)
  - ***Physical Topology*** is the physical layout of the devices connected to the network, including the location and cable installation.
  - The ***Logical Topology*** refers to the way it actually operates (transfers data) as opposed to its layout.
  - Main network topologies (and mixtures of the four): Bus, Mesh (highest cost, highest fault tolerance), Ring and Star (popular, relatively fault tolerant)
- Address and naming models
- Routing infrastructure
  - Static or dynamic?
- Bottleneck identification
- Management strategy
- Service strategy

Security strategy

- Access lists
- Firewall settings
- Network management settings
- Allowed applications
- Critical services
- Physical/premise security

Network Dimensioning process

- Incremental network dimensioning by feedback loop
  - Note that we suggest a measurement based approach:
    - Measure to understand traffic, do analysis and plan for capacity need
  - Alternative approach: Use traffic models (exact models of arrival distributions or such), analyze an plan for capacity needs



Step IV: IP management and planning

- IP subnet planning
  - Every computer on an IP network must have a unique IP address. How many hosts exist in the network? Now and in the future?
  - 2^N-2 nodes/subnets in a network
  - Do you use Private IP addresses (and NAT) or public IP
  - Do you know what is CIDR and what are Class A/B/C addresses?
- Administrative IP servers
  - DHCP, DNS,
    - WINS, LDAP
- Device configuration

Step V: Traffic management

- Traffic peaks can be handled
  - Overprovisioning
  - Priority
  - QoS guarantees (if L2 allows/supports)
- Traffic shaping & policing
  - Filter unwanted traffic
  - Assigned capacity percentages

Technology selection

- Technologies evolve
  - Ethernet was once considered to be solely a LAN technology, now the 10Gbit Ethernet will make it a popular MAN-technology
- Technologies die…
  or feel extremely ill…
  - ATM…!!
- Balance technology potential with existing support and reasonable cost.

Testing, optimizing and documenting

- Test your components and technologies.
- Test applications and services
- Don't assume that your assumptions and calculations hold. Test!
  - Simulate, Emulate and Evaluate
- For large installations, try to build a testing laboratory
- For new services, arrange for pilot projects
- Optimize based on testing results.
- Document everything that you do
  - It will be easier for your successor to pick up where you left ☺

Design of optimal networks

- The path design problem
  - Constrained non-linear optimization problem
    - Find such path configuration $\mathbf{x}_{opt}$ that maximizes the revenue earning rate F(x) subject to constraints such that each path has a strictly positive bandwidth, and that the bandwidths of the paths passing through link use the entire bandwidth of the link.

$$\max_{x} \sum_{a=1}^{A} F(a, x_a) \qquad x_r > 0 \qquad \sum_{r \in R_l} x_r = B_l$$

    - The necessary condition for the configuration to be locally optimal says that the change in revenue obtained by moving an inifitesimal amount of bandwidth to a route (of an aggregate) is equal to the revenue lost in acquiring this bandwidth from aggregates whose path sets include direct paths over the links of the route, and vice versa.

$$\frac{\partial}{\partial x_r} F(a, x_r) = \sum_{l \in r} \frac{\partial}{\partial B_l} F(\cdot, x_l)$$

Things that can go wrong…

- Traffic may experience three different, (layer) independent phenomena in the network :
- All traffic is jammed, stopped or lost.
  - Remedy: Reroute all traffic.
- Data loss and errors.
  - Accept the levels of loss and errors or reroute all or some of the traffic.
- Long-term stability problems.
  - Analyze the network architecture for poor design.

Network simulations as an analysis tool

- Many alternatives to choose from
- Network component interaction
  - > Simulate different options
- Simulation is an economical way
  - to compare alternative solutions
  - sensitivity analysis (if I change something here, what changes over there)
  - problem prediction (bottlenecks)
  - planning for growth

Before simulation, collect data

- Garbage in – Garbage out (GiGo)
- Obtain realistic data
  - perfect data is hard to get, but close enough might be good enough
  - when business is running, measure your network and get simulation parameters from real situations (and extrapolate for future predictions)
    - Models in the simulation must be based on network measurements when necessary (Floyd & Kohler) and possible…

After simulation, analyze data

- Simulations provide you with mass… or mess of data (Kleijnen)
- Be critical, be alert, make sure that you know whether results
  - exist because of or regardless of simulation environment
  - Be especially aware of the sensitivity of the simulation scenario
- Simulations are almost always cheaper to perform than to build the actual network and find out (the hard way) that it's a disaster.

Caveat simulator…

- Simulations have a lot of shortcomings
  - It is difficult to build an exact model of networking equipment
  - Traffic models are not always accurate enough
  - It is hard to model real-life phenomena
    - (Attacks on the network, new services, security level etc.)
  - Read the additional material provided in the course webpage.

Course exercise with ItGuru

- In ItGuru
  - add nodes and components
  - specify the topology
  - configure elements
  - add applications (and configure traffic profiles)
  - run the simulation
  - examine the output
  - (validate results, if possible)
  - change parameters to test different environments
- More details in exercise lectures