# CS 5229
# ADVANCED COMPUTER NETWORKS

2010/2011 Semester 1

Dr. Chan Mun Choon

School of Computing

National University of Singapore

# Network Architecture/Design

# Reading Lists

- [1] D. D. Clark, "The Design Philosophy of the DARPA Internet Protocols,“ ACM CCR Vol. 18, No, 4, Aug 1988, pp. 106-114.
- [2] J.H.Saltzer, et.al, “End-to-end arguments in system design,” ACM Transactions on Computer Systems (TOCS), Volume 2 , Issue 4, Pages: 277 – 288, 1984

- D. Isenberg, The Rise of the Stupid Network, Computer Telephony, August 1997, pg 16-26.

# Before the Internet ...

- PSTN or the Public Switched Telephone Network, is a circuit-switched network that is used primarily for voice communications
- For much of the 20$^{th}$ century, the PSTN was the only bearer network available for telephony, until the arrival of VoIP
- Implications:
  - Voice traffic generates most of the traffic, so the network is designed to be optimized for voice
- PSTN implementation:
  - Circuit switching
  - Dump device, smart network

# The “Smart” PSTN

- PSTN’s Intelligent Network
  - Customization in the network
  - Allow equipment from different vendors to inter-work
  - Focus on (voice) call completion, automation, and billing, e.g. call forwarding, calling card, etc.
  - Any change (new service) needs to go through a very LONG process before it can be deployed

# An example of the problem with "Smart" PSTN

- How to improve voice quality in PSTN
  - "Easy" way: increase voice sampling rate and/or change the coding algorithm
  - But the 64Kbps rate is designed into the network and many components need to be modified
  - Even small changes are difficult because many of the "intelligence" built into the system relies on certain assumptions how other components work
    - changing one component can cause some others to fail
- A design where the network/transport does not make any assumption on the traffic will make changes much easier to implement

# With the Internet ...

- Data traffic volume has overtaken voice traffic ...
- Emergence of packet switching and availability of different access network technologies, e.g. cable modem, ethernet, WiFi etc.

# The "Stupid" Network

- Model: smart device, dumb network
- The best example: Internet
  - Infrastructure/bandwidth is (relatively) cheap and plentiful
  - Always on
  - Network simply deliver the bits, no processing
  - May allow a small amount of customization like different classes of delivery (lower delay, lower loss etc.)
  - Most, if not all customization/application-specific processing are performed at the end-points

# Design Philosophy of Internet Protocols

- Fundamental Goal:
  - Sharing of resources inter-connected network efficiently
- Second Level Goals (in order of importance)
  1. Communication must continue despite loss of networks/gateways
  2. Support multiple types of communication services
  3. Accommodate a variety of networks
  4. Permit distributed management of its resources
  5. Cost effective
  6. Allow host attachment with minimum effort
  7. Resources must be accountable

# 1. Survivability

- Two entities can continue to communicate unless there was no physical path over which any sort of communication could be achieved
- To achieve this goal, state information must be kept somewhere in the network
  1. Stored state in the network and uses replication for recovery
  2. Stored state in the endpoints
- Which one is preferred?

# Cont’d

- Option 2, also called fate-sharing because if the state and the endpoint fail at the same time, is preferred because
  1. More robust against intermediate failures
  2. Much easier to engineer than replication

- Fate-Sharing approach
  - Network is stateless, or datagram network
  - More trust is placed on the endpoint machines than the network to ensure reliability

# 2. Types of Service

- The Internet protocol (IP) is based on a connectionless or datagram mode of service
- The reliability associated with the delivery of a datagram was not guaranteed, but "best effort"
- Type of service is supported **at the transport level**
  - Distinguished by differing requirements on throughput, delay and loss
- TCP was the first service provided in the Internet and was supposed to be general enough to support any type of service
  - TCP ensures reliable, in-order delivery

# Cont'd

- First protocol outside the range of TCP was XNET
  - A cross-Internet debugger
  - The network is not working "correctly", so XNET must work with unreliable delivery
- Another application is the real time delivery of digitized speech
  - One of major source of delay is the error recovery mechanism
  - Need to split TCP and IP, which was originally a single protocol, into 2 separate protocols. UDP was added
- Supporting multiple services proves more difficult than initially thought as new requirements are considered
  - Luckily, reliable delivery is not designed into the network

# 3. Varieties of Networks

- In order to allow the flexibility of connecting of various networks, only a minimum set of assumptions is made about the networks to be connected
  - Network can transport datagram
  - Packet size must be within some reasonable range
  - Requires reasonable low error rate but not perfect reliability
  - Understanding some suitable form of addressing

# Cont'd

- What is missing?
  - Reliable or in-order delivery
  - Broadcast/multicast
  - Priority/differentiation (or in modern terms QoS)
  - Network state information like failure, delay, link utilization etc.
- Customization of service at the transport level
  - Is it possible to make up for these missing features at the end-points?

# Other Goals

5. Cost effective
   - Not as cost effective as a more specialized environment designed for a specific service
   - Header is large (40 bytes for TCP)
   - End-to-end retransmission can be expensive
6. Allow host attachment with minimum effort
   - Requires end host to follow certain rules (think socket programming) ....
7. Resources must be accountable
   - Few tools/mechanisms

# End-to-end Argument

- A function or service should be carried out within a (network) layer only if it is needed by all clients of that layer, and it can be completely implemented in that layer
- This is one of the design principles guiding the "**stupid**" network approach of the Internet
  - Minimize lower layer functions, support the widest possible variety of services, and let the application adapt

- Walter Willinger and John Doyle, Robustness and the Internet: Design and evolution, Robust design: a repertoire of biological, ecological, and engineering case, Oxford University Press, 2005.
  - Some interesting milestones and issues on how the Internet and protocols used have evolved

# Improvements to TCP

- Congestion collapse observed in Oct 1986

- RFC-1122 lists the requirements for a conformant implementation of TCP in 1989

# HTTP/1.0 and TCP

- Interaction between HTTP/1.0 and TCP
  - Known in 1994, addressed by HTTP/1.1 (RFC2616, 1999)
- The “World Wide Wait" phenomenon

# BGP Scaling

- A number of scaling problems with BGP
- One example: size of routing table
- Solution: CIDR

# IP Addresses

- IPv6?
- NAT?

- D. D. Clark, J. Wroclawski, K. R. Sollins, R. Braden, Tussle in Cyberspace: Defining Tomorrow’s Internet, ACM SIGCOMM, Aug 2002, pp. 347-356.

# Tussle in Cyberspace

- The need of Internet has evolved, how best to adapt to the new (competing) requirements ?
- Many more parties involved
  - Users
  - Commercial ISPs
  - Private business user
  - Governments
  - Content Provider

# Design Principles

- Modularity
  - Solutions that less efficient may provide better isolation
  - BAD: DNS used to name machines and trademark. Should provide only location independent names for machines
  - BETTER: Use explicit ToS bits to select QoS rather than say bind the decision to well known ports
- Design for Choice
  - Protocols should be designed such that all the parties to an interaction have the ability to express preferences without breaking the application
  - Example: E-Mail
    - Choice of email reader
    - Choice of SMTP or POP protocols
    - Choice of email (SMTP/POP) servers

# Control

- Who should be in control of what? Example
  - Provider owns the IP addresses
    - Users cannot keep the same IP address when they change ISP – “no number portability”
  - User not allow to provide network-related service, e.g. host web server

# Trust

- One of the most profound and irreversible changes in the Internet is that users do not or cannot trust each other
  - Lost of trust calls for less transparency, and we get firewalls, NAT etc.
  - Desire by ISP for control and application customization produces application level filtering, connection redirection, etc.
  - Desire for performance improvement leads to deployment of caches, mirrors, hacks to DNS etc.

# Openness

- Openness of the network is key to innovation and success of the Internet
  - Openness "encourages" competition
  - Vertical integration, bundling of many services together, requires the removal of certain forms of openness, but may be a useful service to have
  - The ability to <u>deploy a new protocol without having to modify the inside of the network</u> is important

# Future of end-to-end arguments

- End-to-end argument has work well so far
  - Mechanism should not be placed in the network if it can be placed at the end node
  - Core should provide general service, not one tailored to a specific application
- Innovations
  - If the core of the network must be modified to deployed a new application, innovation will be hindered
- Reliability and Robustness
  - If some application states resides in the network, the number of failure points increases. Thus, the simpler the core network, the more reliable is the application

# What might happen?

- Evolution and “enhancement” of existing, mature applications is inevitable
- Failure of transparency will occur
  - Network may not be that “dumb” anymore
- Peeking is irresistible
  - The network can do something good/better if it has more information about the packet/application requirements
  - End-to-end encryption is needed  to protect your privacy
- FIND?
- GENI?

# HW1 Q1

- Read <u>New Times Headlines</u>: **Google and Verizon Near Deal on Web Pay Tiers**
- **Question:**
  a. **What is net neutrality?**
  b. **Do you think net neutrality is a good thing? Explain your point of view.**