Rethinking the Internet Architecture

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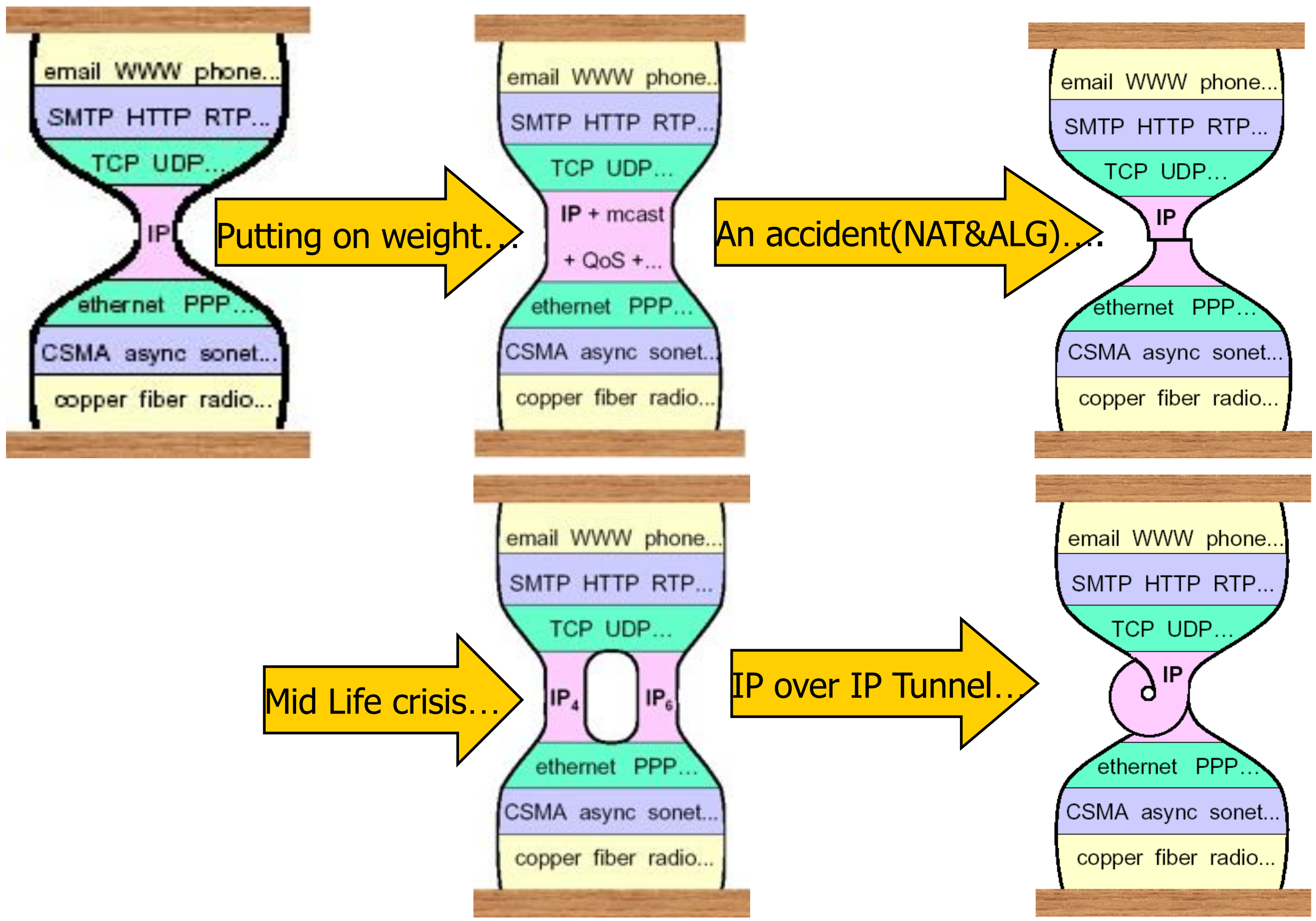
Outline

- The Evolution of the Internet Architecture
- Problems and Challenges
- How to do ?

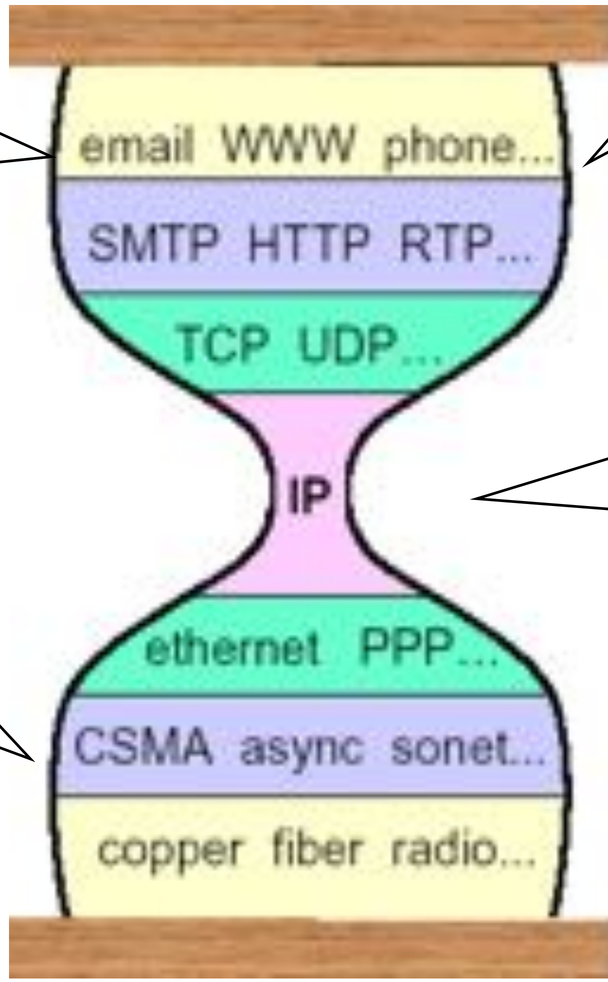
The Hourglass mode of Internet Architecture (From Steve Deering)



Three drivers for the evolution of the Internet Architecture

- New Realtime, Interactive, Multimedia Applications

- Dramatic growth of the Internet:network users and data traffic



Is the IP layer capable of high performance, scalability, flexibility,and reliability?

- Rapid Advances in Optical technologies

The requirements of New Applications

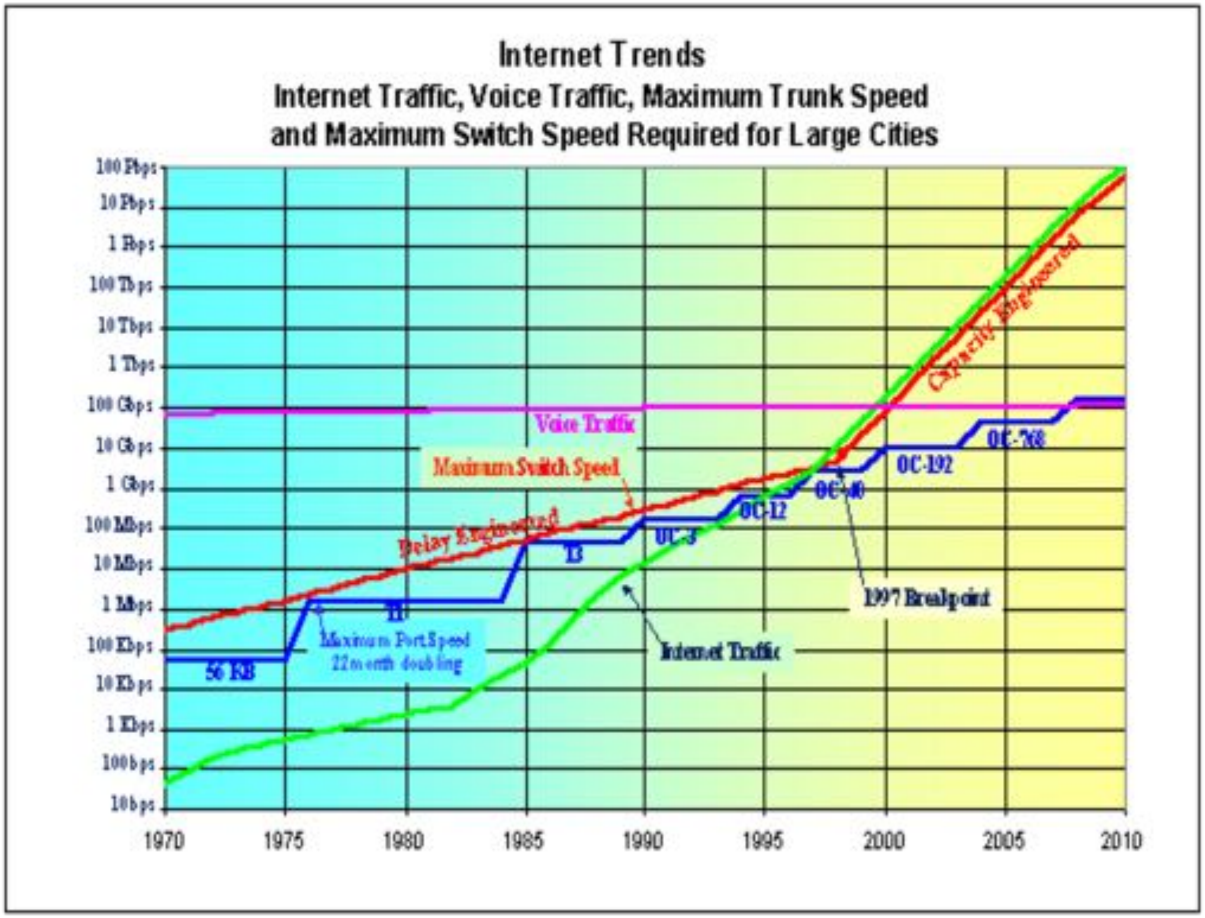
New Realtime, Interactive, MultiMedia applications，such as IP Phone , Video Conference, VOD, Interactive Game, Distance education, medical collaboration and tele-immersive virtual reality

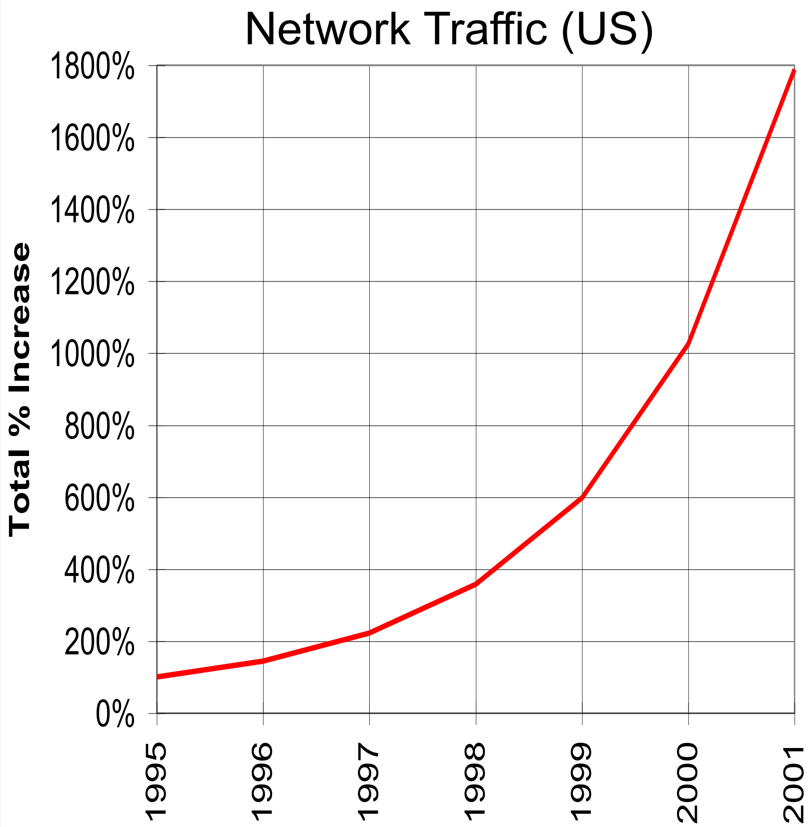
- **guaranteed QoS**
- **larger capacity**

Grid applications, such as computing grid, data grid, p2p

- **Resource sharing**
- **Cooperative working**

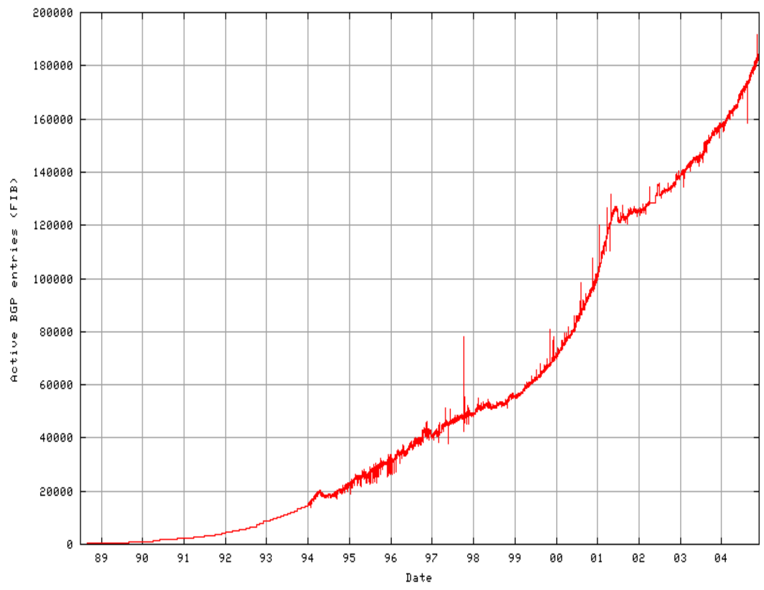
Internet Growth Trend





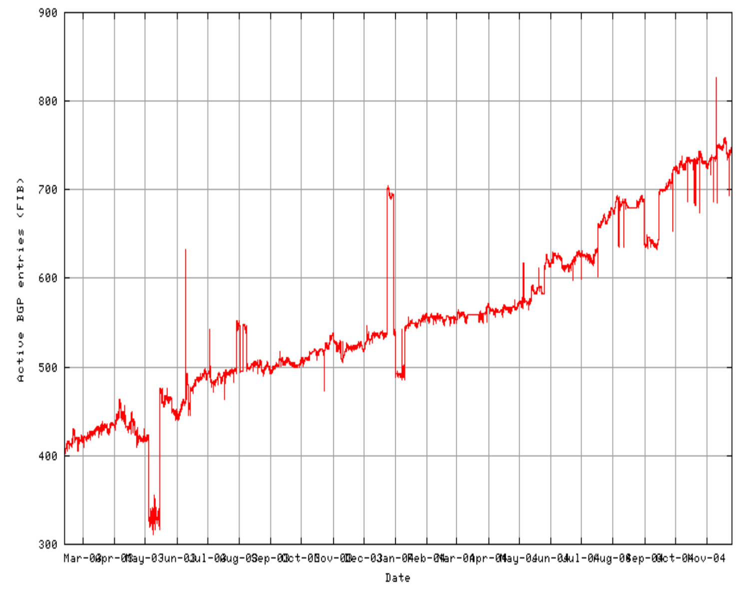
Active BGP entries Growth Trend

IPv4 Active BGP entries (FIB)



- BGP data obtained from *AS1221*.
Report last updated at Thu Nov 25 11:30:35 2004 (Australian Eastern Time).

IPv6 Active BGP entries (FIB)



BGP data obtained from *AS1221*.
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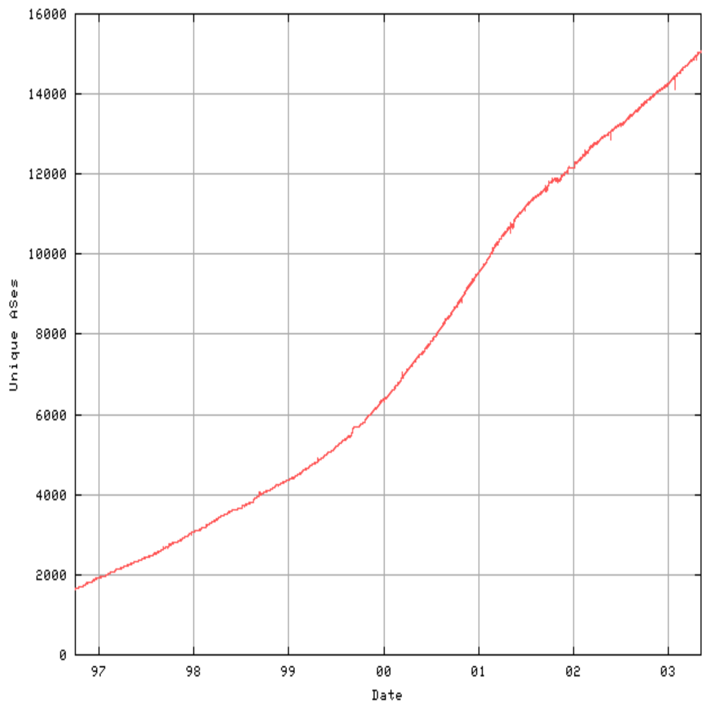
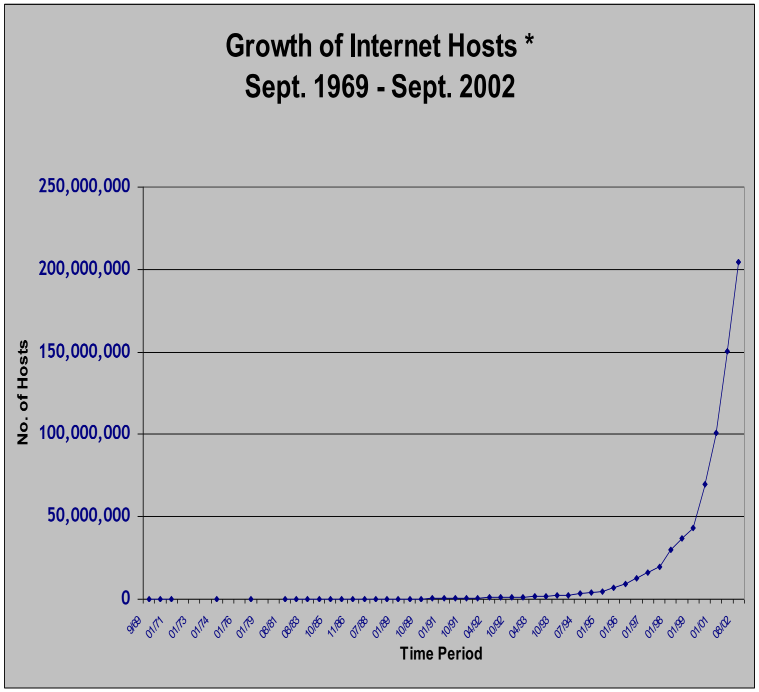
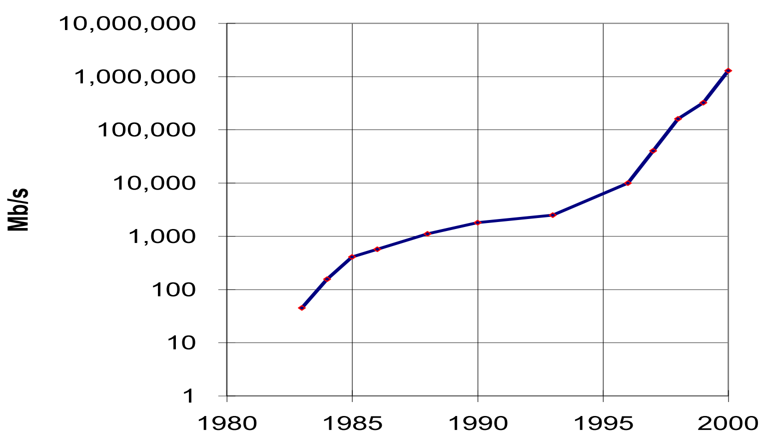
Growth Trend of ASes and Hosts





Rapid Advances in Optical Communication

- Switching technologies：Packet Forwarding、ATM、MPLS、Gigabit Ethernet
- Transport technologies: PSTN、 XSDL、 SONET/SDH、DWDM
- Optical transport technologies, especially DWDM ,are advancing rapidly.
- Optical-Moore Law: Optical capacity doubles every 6 months.
- Optical-Moore Law > 8* chip performance-Moore's Law
- Optical technologies can satisfy the capacity requirements of future communication.

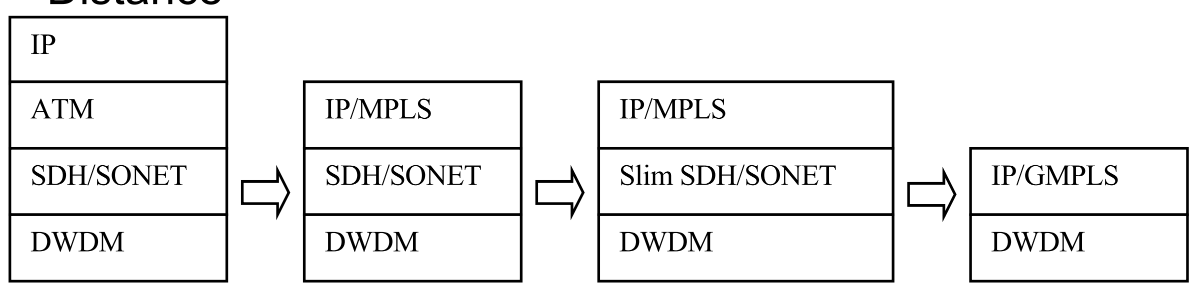


Capacity per Fiber

▲DWDM Channel Growth ： Terabit

▲Bandwidth： 10 Gbps -> 40 Gbps

▲Increased Laser Performance： Greater Distance



The evolution of Optical Internet

Major Challenges to Internet Architecture

- Routing infrastructure
- Quality of service
- Address depletion (IPv4 to IPv6)
- Security
- Etc.

Bottleneck of the Router

- Growth of table size

  --Backbone routers must keep table of all routes (more than 160000 entries)

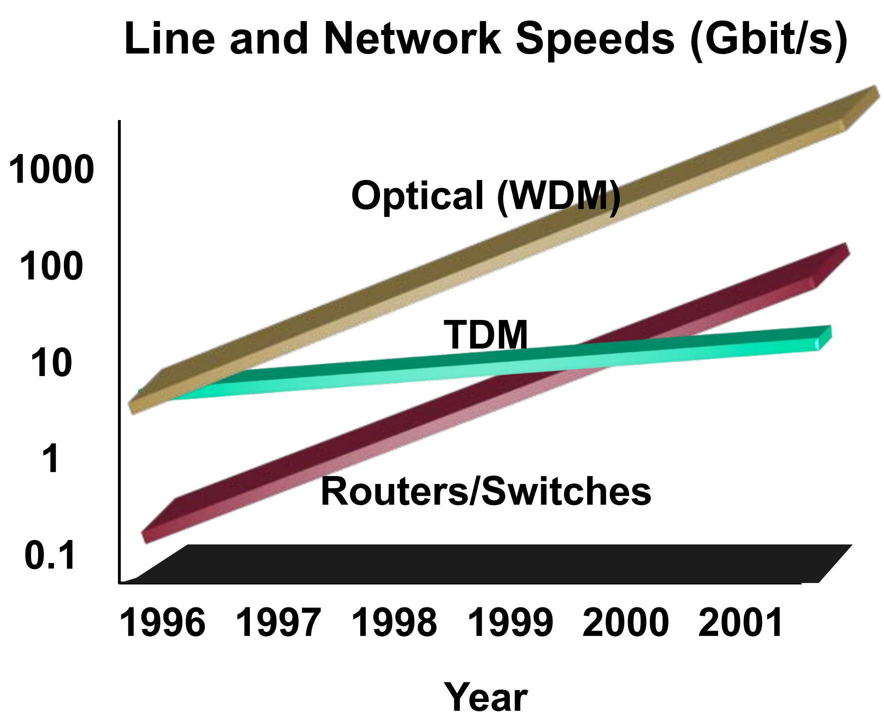
  - Alleviated with CIDR aggregation and NAT
  - Potentially exacerbated if multi-home connections or portable addressing used

- Growth of Link Bandwidth

  --GE->2.5Gbps->10 Gbps -> 40 Gbps

Bottleneck of the Router

- Internet Traffic doubles 6 months(1997-2008)
- Semiconductor performance doubled every 18 months(Moore's Law)
- One result of the extremely high growth rate of the traffic (4 x per year) is that the maximum speed of core routers/switches must increase at the same rate, the first time in history that improvements have been required faster than the improvement rate for semiconductors, Moore's Law.



Bottleneck of the Router

- Performing many complex operations at a router's line card: including processing the packet header, longest prefix match, generating ICMP error messages, processing IP header options, and buffering the packet , route and packet filtering, or any QoS or VPN filtering.
- Increasing Forwarding Performance
  - Lambda switching, MPLS --Too Complex for IP Core Layer (LDP/RSVP)
    - Eliminate intermediate IP route lookups
    - DWDM requires extremely fast forwarding
    - At edges, map traffic based on IP address to wavelength or other non-IP label
    - Wavelength or label switch across multiple hops to other edge
  - Faster IP lookups--Limited improvement to Performance
    - Data structures and algorithms for fast lookups

Challenges to Routing Protocols

Two-tier routing infrastructure which including inter-domain routing(BGP4) and intra-domain routing(OSPF etc.) exists problems:

- Routing instability
  - global convergence on a withdraw or a new route to roughly 30 *N seconds
  - Frequency of updates increases with size
  - Update damping occuring already
- Potential for breakdown in connectivity
- Other challenges
  - Policy-based routing, packet classification
  - Non-destination-based routing
  - Route-pinning for QoS
- Reducing state in the network:Why Global state at every backbone router? Other non-global approaches?

Challenge of QoS

- The initial propose of Internet is to carry data traffic without QoS guarantee in nature.
- The remedy for QoS such as IntServ/RSVP, DiffServ, MPLS-TE and Constrained based Routing make the core IP layer more complex.
- It is difficult to build QoS connection in connectionless network. The build and maintain of the connection consumes precious network resource and competes with the user data.
- It is difficult to maintain Route-pinning for QoS.
- The nature of QoS routing is a NP-complete problem.

Conclusions on Challenges to Internet

- As network size, link bandwidth, CPU capacity, and the number of users all increase, research will be needed to ensure that the Internet of the future scales to meet these increasing demands.
- Optical transport technologies is expected to meet the capacity requirements of Internet growth, however, the routing and switching technologies of IP layer linked with the Moore's law is becoming the bottleneck of information infrastructure.
- The routing protocols is too complicated to meet all requirements.
- The radical reason to routing and QoS challenges is enormous and complicated Internet structure. So far, no universal model can analyze and predict the dynamic changing internet topology,traffic pattern and resource distribution.
- These design principles of current internet are not suit for high-performance, scalable, manageable global information infrastructure.
- Hence, is it necessary to develop a new generation network architecture or take problem-patching approach to face these challenges?The goal of the research must be not only to meet the challenges already experienced today, but also to meet the challenges that can be expected to emerge in the future.

Rethinking of some design principles

- Reliability(unstructured, decentralized topology +Arbitrary mesh connection +Dynamic routing +packet Switching) vs. High performance (Optimal topology for efficiency)

  The evolution of protocols can lead to a robustness/complexity/fragility spiral where complexity added for robustness also adds new fragilities, which in turn leads to new and thus spiraling complexities.
- Flat IP address space(large size table looking up) vs. structured address space
- Isolation the topology from global IP Addressing vs. tight coupling

Understanding Internet Topology

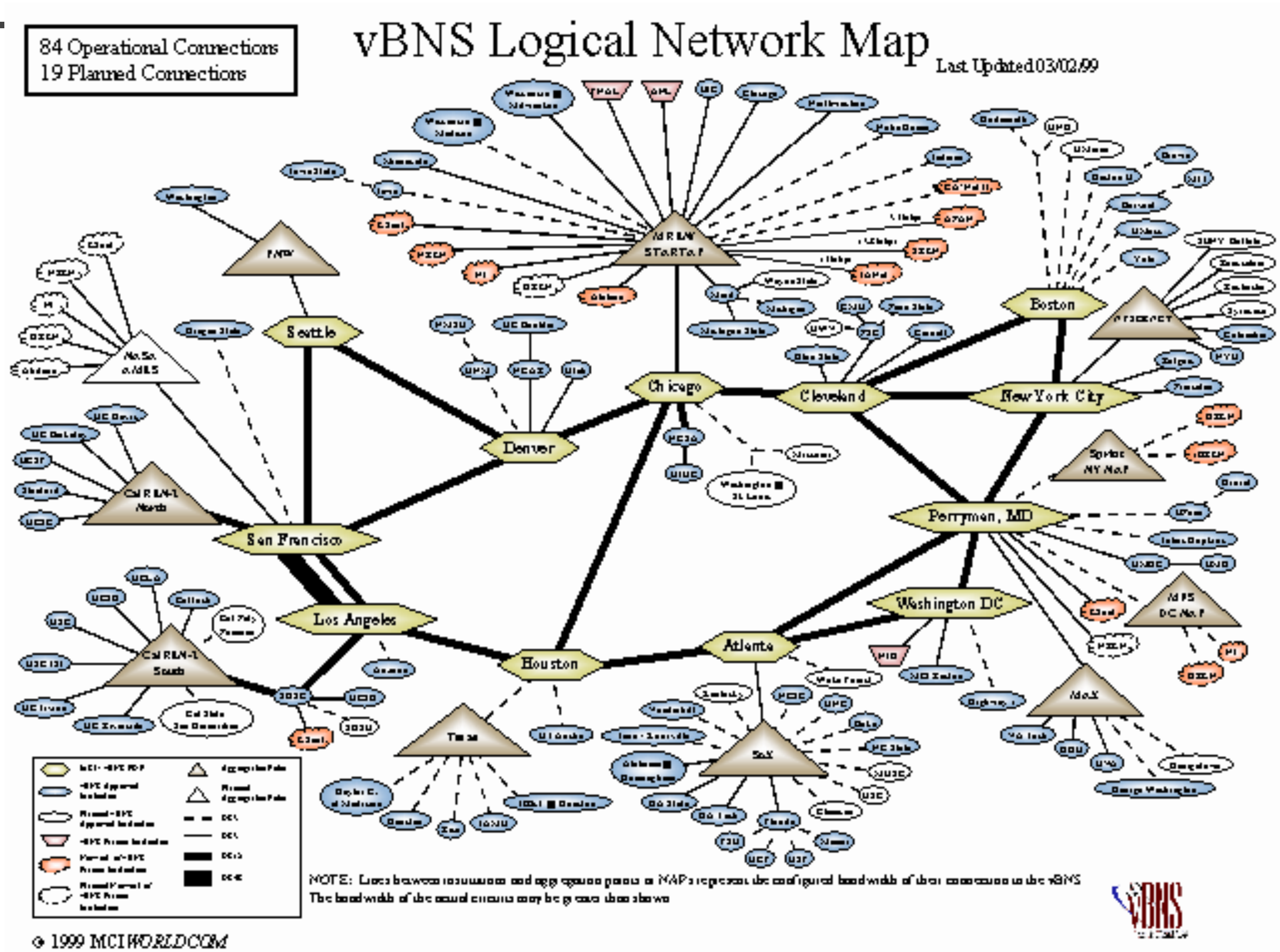
Benefits from understanding Internet topology

- Protocol Design: Design more efficient protocols that take advantage of it's topological properties
- Performance evaluation: Create more accurate artificial models for simulation purposes
- Estimate topological parameters and traffic patterns

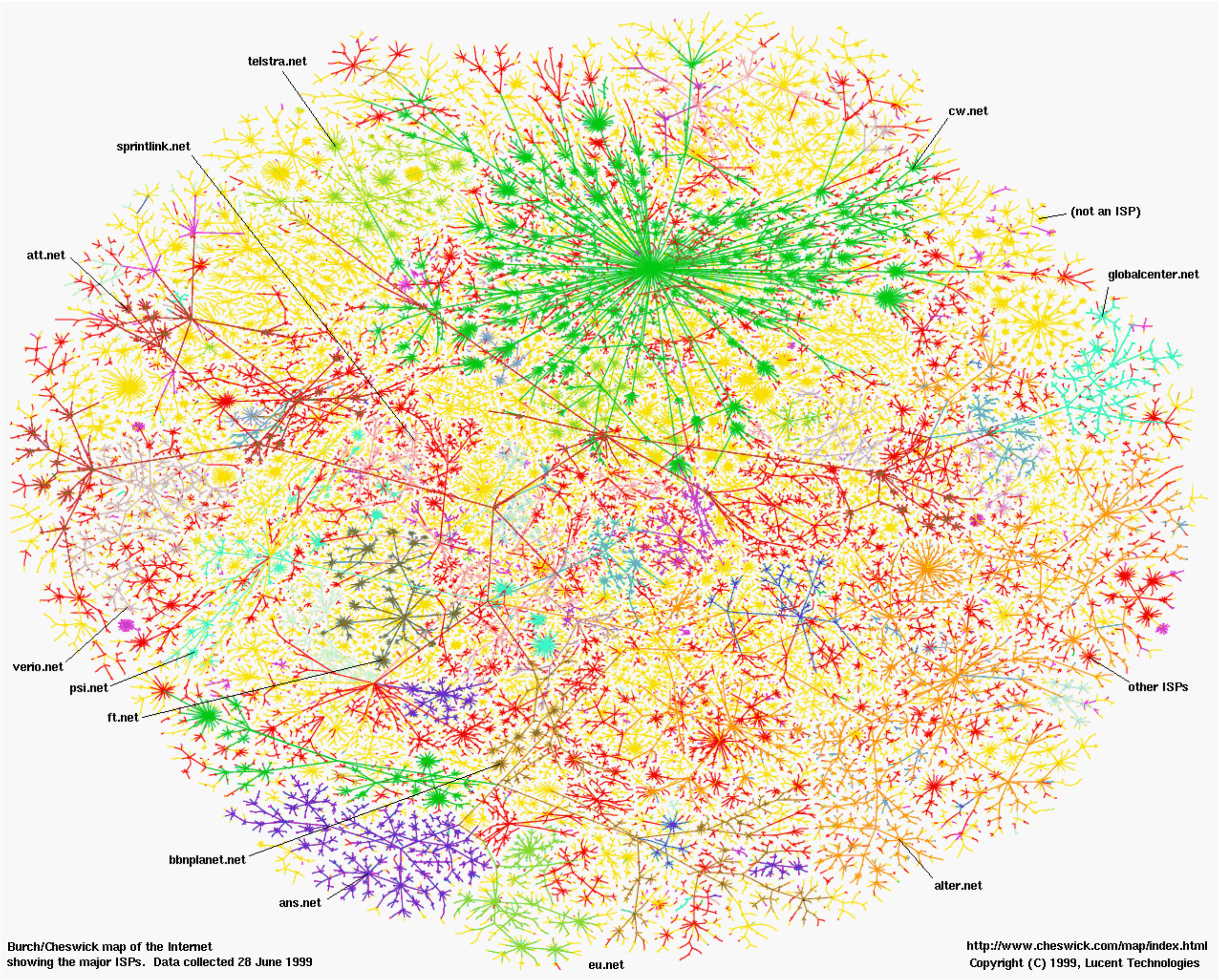
Study the topology of Internet at Three level of granularities

- Router Level
- Cluster level
- Inter-domain Level

vBNS Logical Network Map: A Tree-like Structure



Internet Map showing the major ISPs: a large tree-like structure



Understanding Internet Address architecture

- What is naming, addressing and routing?
  - a name identifies what we seek
  - an address identifies where it is
  - a route tell us a way to get there
- In a flat address space, an address behaves more like an identifier than an address
- In a hierarchical address apace, such as phone systems, the address behaves as a source route to aid in routing the packet.
  - Provider based Address assignment:

    Provider.subProvider.subscriber
  - Geographical based Address assignment:

    Continent.country.metro.site

IPv4 Address Aggregation

- The originally IPv4 addresses formed a class based hierarchical structure.
- Subnetting was introduced in order to use the network numbers more efficiently.
- CIDR is based on aggregate routes, and was introduced in order to
  - Reduce the size of backbone routing tables, One entry in a routing tables is enough to tell how to reach several networks
  - Alleviate IP address exhaustion and address assignment is more efficent

IPv6 Address Architecture

- IPv6 defines aggregatable global unicast address format.
  - support of provider and exchange based aggregation. The combination will allow efficient routing aggregation for sites that connect directly to providers and for sites that connect to exchanges.
  - separation of public and site topology. Aggregatable addresses are organized into a three level hierarchy, Public Topology, Site Topology, Interface Identifier
  - support of EUI-64 based interface identifiers

IPv6 Address Architecture

- Top-Level Aggregation Identifiers (TLA ID) are the top level in the routing hierarchy.
- Next-Level Aggregation Identifier's are used by organizations assigned a TLA ID to create an addressing hierarchy and to identify sites.
- The SLA ID field is used by an individual organization to create its own local addressing hierarchy and to identify subnets.
- The design of an allocation plan is a tradeoff between routing aggregation efficiency and flexibility.
- Creating hierarchies allows for greater amount of aggregation and results in smaller routing tables.
- Flat assignment provides for easier allocation and attachment flexibility, but results in larger routing tables.

3b	13b	8b	24b	16b	64b
FP	TLA ID	RES	NLA ID	SLA ID	Interface ID
Public Topology				Site Topology	

The aggregatable global unicast address format

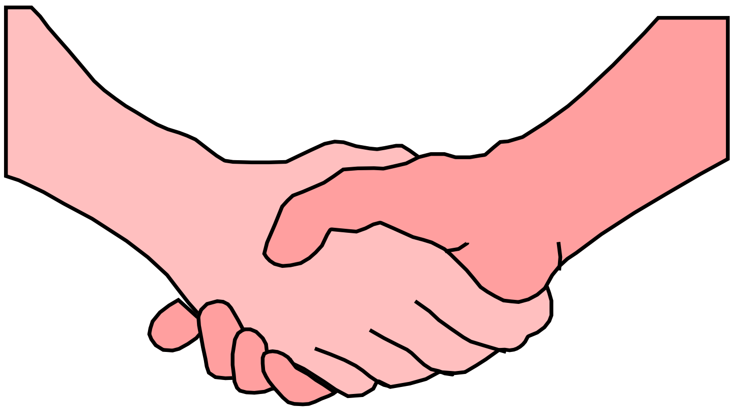
How to do at Internet Architecture level?

- The Map of Internet topology is a large tree-like structure, and the addressing architecture supports address aggregation.
- Have we really explored all possible ways to aggregate? Can we Search for scalable and hierarchical architecture? Other methods?
- How to design more efficient protocols that take advantages of optimal topology and aggregated addressing in the currently existing Internet architecture? Is it really a true nonsense?

Possible solution?

- In particular, the Simplicity Principle states complexity must be controlled if one hopes to efficiently scale a complex object.
- Keep the core IP layer efficient and simple, Which is soul of the design principles of Internet.
- The hierarchical structure which may imply simple topology and relative fixed route is suit to build large scale systems.(Phone system)
- The property of well-structured hierarchies will simplifies the routing ,forwarding operations and QoS remarkably.
  - minimize global exchanging routing information and computing route table.
  - Control the number of route table entries easily.
  - The control and management are simple.
- Are these keys to construct a high-performance, scalable architecture for the future Internet?

Thank you !



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