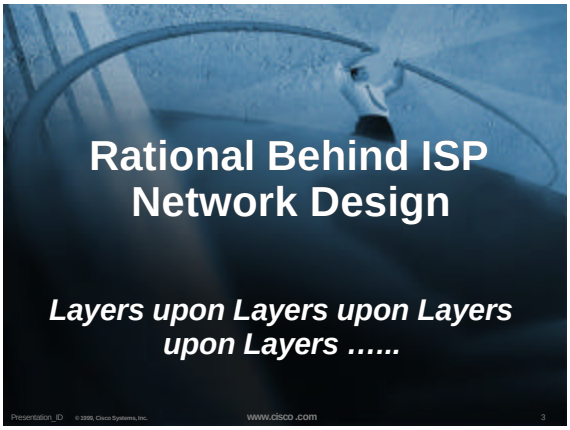
Agenda

- Rational Behind ISP Network Design
- Point of Presence Topologies
- Adding Services to the Architecture
- Impact of Services on the Network



The Free On-line Dictionary of Computing

Architecture: Design; the way components fit together; it may also be used for any complex system, e.g. “software architecture”, “network architecture”

Network Design and Architecture…

- … can be critical
- … can contribute to the success of the network
- … can contribute to the failure of the network

Ferguson’s Law of Engineering

“No amount of magic knobs will save a sloppily designed network”

Paul Ferguson—Consulting Engineer, Cisco Systems

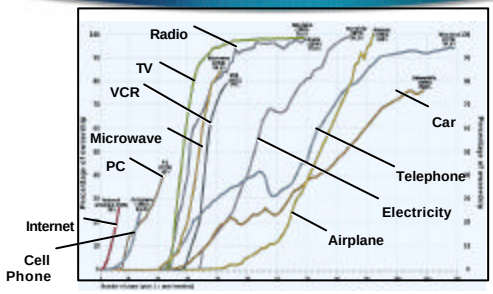
What Is a Well-Designed Network?

- One that takes into consideration some main factors
  - ✓ Topological/protocol hierarchy
  - ✓ Redundancy
  - ✓ Addressing aggregation (IGP and BGP)
  - ✓ Scaling
  - ✓ Policy implementation (core/edge)
  - ✓ Management/maintenance/operations
  - ✓ Cost

One Must Acknowledge that…

- Two different worlds exist
  - ✓ One world revolves around private organizational networks and another concerns the global Internet
- Growth in the Internet is faster than any other technology introduced to the public-at-large

Technology Adoption



Scaling is the #1 Problem on the Internet

> ***"If you're not scared yet, you don't understand the problem!"***

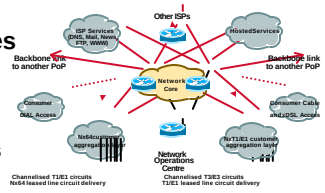
Core Influences to ISP Design

- Modular Design
- Functional Design
- Tiered/Hierarchical Design
- Multiple Levels of Redundancy
- Routing Protocol Hierarchy
- Build for IP Forwarding First - then add services

Modular Design

Organize the Network into separate and repeatable modules

- ✓ Backbone
- ✓ POP
- ✓ Hosting Services
- ✓ ISP Services
- ✓ Support/NOC

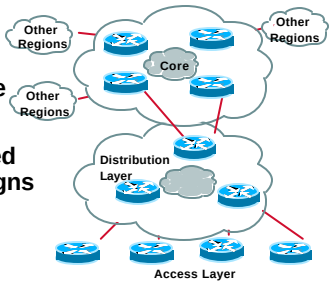


Functional Design

- **One *Box* cannot do everything!** (no mater how hard people have tried in the past)
- **Each router/switch in a network has a well-defined set of functions.**
- **The various *boxes* each with a function interact with each other.**
- **ISP Networks are a *systems* approach to design.**

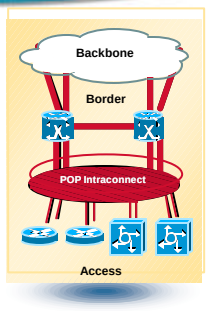
Tiered/Hierarchical Network Design

- **Flat - Meshed Topologies have not scaled.**
- **Hierarchy is used in network designs to scale the network.**



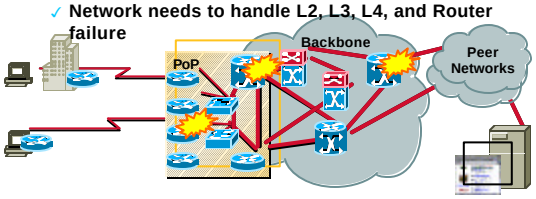
Multiple Levels of Redundancy

- **Triple Layered POP Redundancy**
  - ✓ **Lower-level failures are better**
  - ✓ **Lower-level failures may trigger higher-level failures**
  - ✓ **L2: Two of everything at**
  - ✓ **L3: IGP and BGP provide redundancy and load balancing**
  - ✓ **L4: TCP re-transmissions recovers during the fail-over**

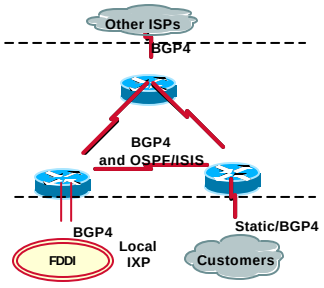


Multiple Levels of Redundancy

- **Objectives -**
  - ✓ **As little user visibility of a fault as possible**
  - ✓ **Minimize the impact of any fault in any part of the network.**
  - ✓ **Network needs to handle L2, L3, L4, and Router failure**



Hierarchy of Routing Protocols

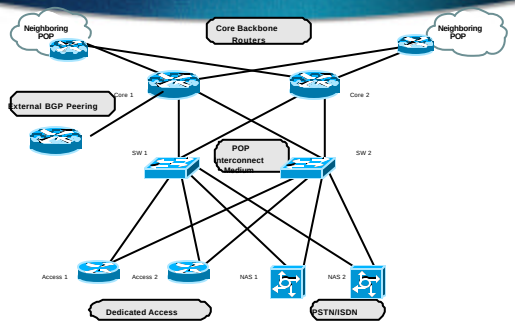


Warning

"Beware Block Diagram/ Slideware *Design Gurus!* They have gotten people and networks into trouble - including Cisco"

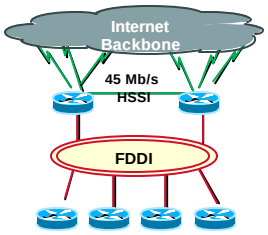
Point of Presence Topologies

PoP Design



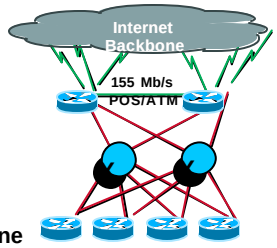
Early Internet POP Architecture - NSP

- ✓ Backbone trunks at 45 Mb/s
- ✓ Shared media interconnect within POP:
  - FDDI, Ethernet, Switched Ethernet
- ✓ Conventional T3 backbone Internet router



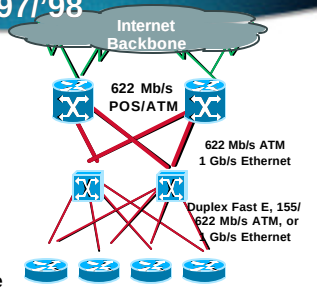
Internet POP Architecture - '96/'97

- ✓ **Backbone trunks at 155 Mb/s**
  - **Packet over SONET OC3**
  - **ATM OC3**
- ✓ **Switched interconnect within POP:**
  - **Switched FDDI/Fast Ethernet**
  - **ATM OC3**
- ✓ **Advanced OC3 backbone Internet router**



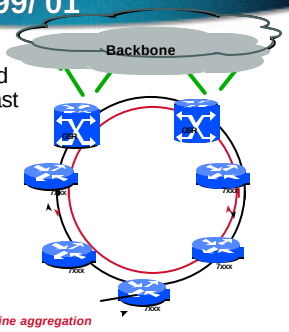
Internet POP Architecture - '97/'98

- ✓ **Backbone trunks at 622 Mb/s**
  - **Packet over SONET OC12**
  - **ATM OC12**
- ✓ **Switched interconnect within POP:**
  - **ATM at OC3 AND OC12**
  - **Ethernet Channel**
  - **Gigabit Ethernet (early '98)**
  - **POSIP (late '98)**
- ✓ **Gigabit OC12 backbone Internet router**



Internet POP Architecture - '99/'01

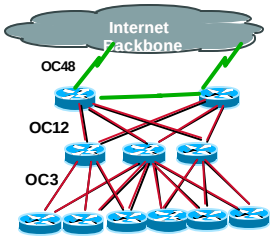
- • **SRP Rings -** High Speed of SDH combined with fast failover and redundancy
  - ✓ High bandwidth
  - ✓ Reduced port counts
  - ✓ Reduced complexity
  - ✓ Proactive self healing



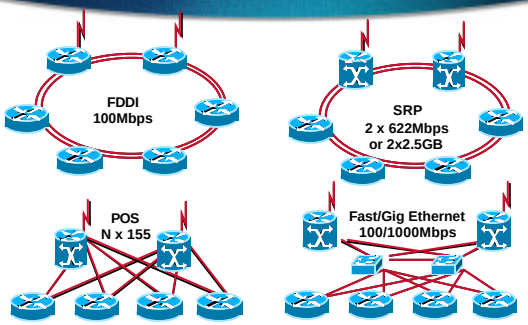
leased line aggregation

Large POPs - add a 3rd layer

- ✓ Problem: port density!
- ✓ Solution: buy more routers!
- ✓ Customer routers connect to aggregation routers
  - Packet over SONET OC3
  - ATM OC3
- ✓ Aggregation routers connect to backbone routers
- ✓ Scales nicely
- ✓ X CRs to Y ARs to Z BRs
  - ✓ ...where X>Y>Z
  - ✓ Be careful not to oversubscribe!

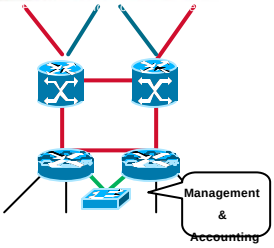


POP Interconnect Summary



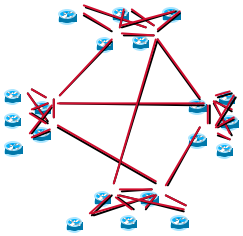
Key Design Principles

- **Interconnection for Management, Security, and Accounting services**
  - ✓ Netflow Devices - FlowCollector
  - ✓ Syslog collector for all network devices
  - ✓ SNMP collector (PC Based UNIX)
  - ✓ Security Auditing Tools (NetSonar)



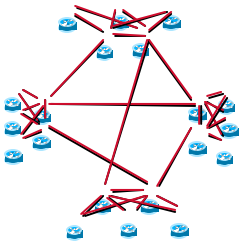
ISP routing Architectures - IP

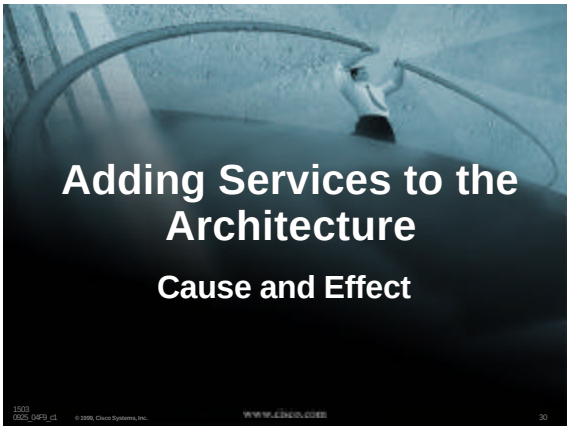
- IGP = EIGRP, IS-IS,or OSPF
  - ✓ *almost always* IS-IS or OSPF
  - ✓ IS-IS, single level (usually L2)
  - ✓ OSPF, either single area or BB/POP areas
- BGP = all routers in full mesh
  - ✓ mesh accomplished with route reflectors, confederations, actual full mesh
- All routers have all routes, so services could go anywhere



ISP routing Architectures - IP+MPLS

- IGP = EIGRP, IS-IS,or OSPF
  - ✓ *must* be IS-IS or OSPF to use MPLS TE
- BGP = only edge routers need full routes
  - ✓ full-mesh of edge routers using aforementioned mechanisms
  - ✓ packets are forwarded via LDP labels, not IP destination address
- Where to put your services?
  - ✓ cannot hang a cache service off of a router that doesn't have full routes!





Services? How many *Services*?

Most network services are applied at the edge!

Edge (one-time) services

- Voice over IP
- MPLS VPNs
- CDNs
- VPDNs
- Managed services
- Dial—DSL—cable

Per-hop services

- MPLS packet forwarding
- DiffServ, other QoS
- Multicast Services

Ask the Right Questions

- What is the value of the service?
  - ✓ Technical merit
  - ✓ Cost savings
  - ✓ Marchitecture
- What is the cost of the service?
  - ✓ Equipment?
  - ✓ Training people to support it?
  - ✓ Network buildouts/topology changes?

Who Knows?

- What will be the impact on existing traffic loads/patterns?
- Can the network deliver the performance that your customers/applications desire? delay? jitter (delay variation)?
- Make sure to add capacity as you add services - bandwidth is a must.

Deployment of New Services

- Is more of a business decision
- The technical aspect is to ensure continued network performance—scalability and stability
- Try to keep services within your AS
  - ✓ end2end control
  - ✓ less likelihood of failure/flaps

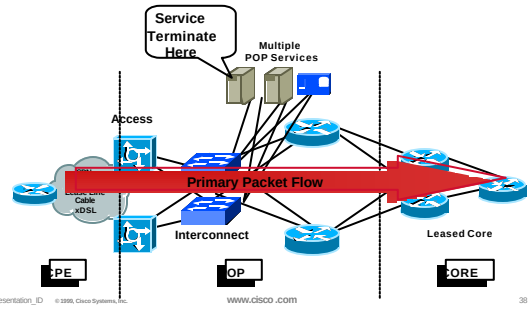
Deploying New Services

- Don't feed the hype fire
- Look *before* you leap!
- Don't deploy new technologies and services just for the sake of it; have valid business and technical reasons

Deploying New Services

- Usually a Service requires a TCP/UDP termination (I.e. TCP's three way handshake)
- Termination should happen out side of the *primary flow path*
- Otherwise, the network is then designed around the single service.

Deploying New Services



Transparent Redirection of a Flow in the POP

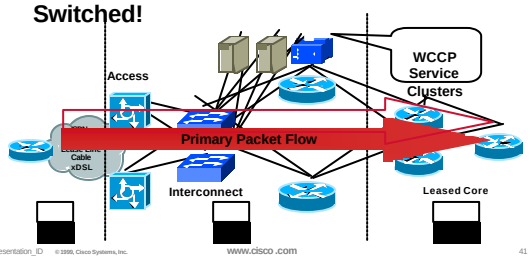
Factors that went into the design of WCCP

Design Objectives for the ISP

- Transparent *Redirection* of a IP flow based on source, destination, and/or port number.
- Transparent *Integration* - no rebuilding the POP to add this service.
- Failed open - if the service fails, it should not effect the core IP service nor any other services.

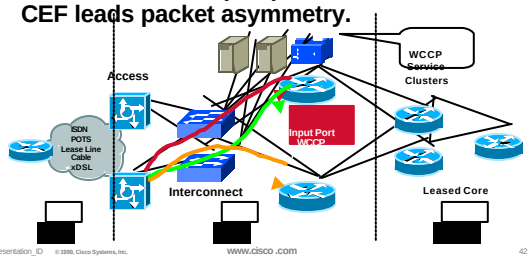
Design Objectives for the ISP

- Not to effect the primary packet flow of the POP - if not redirected - then is CEF/dCEF Switched!



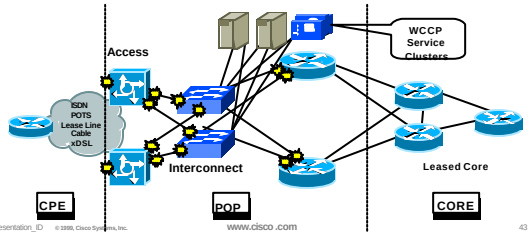
Design Objectives for the ISP

- Work with the multi-level L2/L3 redundancy of the ISP POP. Equal paths in the IGP + CEF leads packet asymmetry.



Design Objectives for the ISP

- Provide the ISP with Flexibility on the point of redirection. Do not force an architecture on the customer.



Design Objectives for the Service Group

- Linear Scalability with the Cache - minimize object replication.
- Fault Tolerance and Maintenance.
- "Joe Smith the Telco Tech" test.

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