The value of Internet is in global reachability
- Reachability comes from co-operative peering efforts
  - Customer peering (Customer-Provider-Customer relationship)
  - Shared cost peering (Provider-Provider relationship)
- There are roughly 18000 players
  - 13000 of them are Stub ASs
  - 78 are pure transit providers
  - 5000 do both

The structure of Internet is chaos
- Thousands of service providers with highly varying principles in their operation

How packet finds its route through the black box
- BGP forms a structured layout of the whole Internet for packet level transport
  - Reflects the semi-optimal contractual agreements between operators along the route of the packet

Why accepting packets from fellow ISP
- Economic impact
  - Transit traffic
- Reciprocity
  - Cost reduction
Agreements

- Form the basis between inter-provider communications
  - Small ISPs are customers of larger ones
    - Larger ISPs deliver their customer traffic as their own traffic
    - Larger ISPs deliver their customer traffic as transit traffic
  - Equal size providers exchange their traffic pro bono
    - Both save money by interconnecting directly rather than through 3rd party
    - Mutual agreement for exchanging only their customer traffic

Strict hierarchy

- Based on structural and regulated manner of forming customer/provider relationships
  - Valid in telco operations
  - Operators for a chain of customer/provider relationships
  - Based on regulation of operational arena
    - Local operators
    - Long distance operators
    - International operators
  - Cash flows to the top of the hierarchy
    - Local operators collect the money from end users
    - Middle layers take their premiums

Loose hierarchy
Loose hierarchy

- Local providers compete the local market but share common need to exchange their customer traffic on a local level
  - It is profitable for all to have direct exchange of traffic without 3rd parties
    - Better marginal revenue
  - Requires
    - Interconnection points
    - Bilateral agreement to establish equality
      - Zero payment principle
        » Both parties benefit from peering
        » No mutual transfer of money

Internet

- Naturally loose in hierarchy
- Local ISPs maximize their revenue by minimizing their transit traffic
- Same structure on all levels of hierarchy
- Any connection through the Internet is formed with chain of customer/provider relationships with a single zero payment border
  - Cost of connection is therefore divided into two
    - From source to top of the chain
    - From destination to top of the chain
  - Peering does not cover transit traffic
    - Only one zero payment border

Transit domain

- A transit domain allows external domains to use its own infrastructure to send packets to other domains

- Examples
  - FuNET, NorduNET, GEANT, Internet2, BT, Telia, Level3,...
Stub domain

A stub domain does not allow external domains to use its infrastructure to send packets to other domains. A stub is connected to at least one transit domain:
- Single-homed stub: connected to one transit domain (S1)
- Dual-homed stub: connected to two transit domains (S2-S4)

Examples:
- Content-rich stub domain
  - Large web servers: Yahoo, Google, MSN, TF1, BBC, ...
- Access-rich stub domain
  - ISPs providing Internet access via CATV, ADSL, ...
  - Saunalahti, Kolumbus, Weiho etc

Internet

- Tier-1 ISPs
  - Dozen of large ISPs interconnected by shared-cost peering arrangements
  - Form the core of the Internet
  - Provide transit service for T2/T3 service providers

Tier-1 service providers

- AOL Transit Data Network
- AT&T
- BBN
- British Telecom
- Cable and Wireless
- Connect Internet Solutions
- Deutsche Telekom
- Global Crossing
- Level 3
- NTT/Verio
- Optus
- Primus Telecom
- Qwest
- Sprint
- Telstra
- UUNET
- WilTel (Williams Communications)
### Internet

- **Tier-2 ISPs**
  - Regional or National ISPs
  - Customer of T1 ISP(s)
  - Provider of T3 ISP(s)
  - *shared-cost* with other T2 ISPs

### Tier-3 ISPs

- Smaller ISPs, Corporate Networks, Content providers
- Customers of T2 or T1 ISPs
- *shared-cost* with other T3 ISPs

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### Customer-provider peering

- **Principle**
  - *Customer sends to its provider its internal routes and the routes learned from its own customers*
    - Provider will advertise those routes to the entire Internet to allow anyone to reach the *Customer*
  - *Provider sends to its customers all known routes*
    - *Customer will be able to reach anyone on the Internet*

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### Shared-cost peering

- **Principle**
  - *PeerX sends to PeerY its internal routes and the routes learned from its own customers*
    - PeerY will use shared link to reach PeerX and PeerX's customers
    - PeerX's providers are not reachable via the shared link
  - *PeerY sends to PeerX its internal routes and the routes learned from its own customers*
    - PeerX will use shared link to reach PeerY and PeerY's customers
    - PeerY's providers are not reachable via the shared link
Shared-cost peering

- AS1 send routes of AS{1,3,4,7} to AS2
- AS2 sends routes of AS{2,4,7} to AS1
  - Not AS3 while those routes come from shared-cost peering
  - Routes from shared-cost peering are not advertised to providers

Internet exchange

- **Commercial starting point**
  - A company builds an interconnection point to
    - Gain revenue from peering traffic
    - Gain revenue from transmission links coming to exchange
    - Gain revenue from transit traffic

- **Co-operative starting point**
  - Neutral partner runs the exchange
    - None of the partners owns the premises
    - None of the partners owns the transmission links into exchange
    - None of the partners owns the equipment in exchange

Internet

- **Local providers aim to minimize their expenses by interconnecting at local level**
  - **Local exchange points**
    - .CIX (Commercial Internet eXchange)
    - MAE.. (Metropolitan Area eXchange)
    - NAP (Network Access Point)
    - IXP (Internet eXchange Point)
    - EP (Exchange Point)
  - **Bilateral interconnections**

Internet exchange

- Build over L2 technology
  - Ethernet, ATM, FrameRelay switch
- Each provider connects into shared media with transmission link terminated to border router of provider
  - Everybody is able to see everybody
Internet exchange

- Peering agreements can be based on
  - **Multilateral agreements**
    - Every partner is peering with every other partner
    - All border routers share a common subnet which is not filtered
    - Ideal situation for Ethernet type of IXP solution

- **Bilateral agreements**
  - Partners peer only based on bilateral agreements
    - Requires L2 technology that is able to create virtual connections between peering partners
      - ATM PVC
      - FR DLCI
      - Ethernet VLAN

- **Multilateral peering requires either**
  - Separate BGP session between each border router
    - N(N-1) sessions
  - IXP offers route server capabilities
    - Only N sessions
    - BGP-route reflector

- Depending on operational philosophy of IXP
  - Partners can make bilateral transit agreements in IXP
    - Partners are already in same premises
    - Required separate virtual connections between transit provider and customer
  - Partners can make QoS peering
    - Several virtual connections between peers
      - One per VPN per QoS class
      - One per MPLS LSP
      - etc