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 48000 assigned AS numbers from which about 24000 are advertised to BGP i.e. are players
  - 21165 of them are Stub ASs
  - 83 are pure transit providers
  - 3082 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)

**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**

- **AT&T (AS7018)**
- **Global Crossing (GX) (AS3549)**
- **Level 3 (AS3536)**
- **Verizon Business (formerly UUNET) (AS701)**
- **NTT Communications / (formerly Verio) (AS2914)**
- **Qwest (AS209)**
- **SAVVIS (AS3561)**
- **Sprint Nextel Corporation (AS1239)**

- Dozens of other providers are also marketed as T1 where as they are not
  - They have
    - Transits
    - Paid peering

**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, Welho etc
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

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

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 sends 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

**Direct Approach**

- In direct approach peering negotiations are established with open cards
  - Official invitation to peered AS to start negotiations
    - Results
      - Peering formed
        » Direct
        » Partial
        » Conditional
      - Peering not formed

**Migration tactics**

- Initially transit connection is bought with option to peer when conditions are met
  - Incentive of accumulated cash flow for period of time
  - Risk of not having peering conditions met or changed conditions over the time

**Selected transit**

- Transit connection is bought from provider which is not a candidate of future peering
Traffic Manipulation

• Force traffic to routes that make peering look attractive
  – After while initiate peering negotiations
  • Upstream traffic does not generate fast incentives

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

Traffic Manipulation

• Force traffic to routes that make peering look attractive
  – Stop advertising routes to cheap directions
  – Falsely inject AS#2 to path vectors in direction of AS#1
    • Loop detection prevents routes to be installed at AS#2

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 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

- 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
Internet exchange

- 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

Material about peering

- **Peering**
  - As general
  - Motivations
  - Tactics
- **IXP**
  - How-to
    - [http://www.euro-ix.net/ixp/startingixp/](http://www.euro-ix.net/ixp/startingixp/)