Economics of IPv4 Markets on IPv6 Deployment

Andrew Dul

andrew.dul@quark.net
The money underlies much of what we do
When we push against the economics we are pushing up hill…which is hard
Since “the beginning of the Internet” allocations have been based on need

Over time this process was formalized into RFCs and later into RIR policies

The RIRs saw the need to for allowing transfers of IPv4 addresses after exhaustion

Transfer policies were created to allow economics to effect transfers
Pros & Cons of an IPv4 Market

- **Pros**
  - Allows economic factors to bring IPv4 addresses to the right place in the market place
  - Increases the economic cost of IPv4 potentially forcing users to consider IPv6

- **Cons**
  - Potentially delays (or maybe deters) the adoption of IPv6
  - Deaggregation creates more routing table entries from larger blocks being “chopped up” to sell or lease
The IPv4 market to date

- Large known transaction from Nortel Bankruptcy to Microsoft in 2011
  - 667k IPv4 addresses for $7.5 million USD
    - $11.25 USD per IPv4 address
- Other small transactions have occurred
- Address brokers are forming
  - [http://ipv4ex.com/](http://ipv4ex.com/)
  - ARIN has a listing service
Demand continues to increase; the supply is finite and now scarce.

RIR Allocations to organizations

Current demand exceeds 250 million addresses per year.
Demand appears to be tied to growth of economies

IPv4 Allocations vs. World GDP

$y = 0.0007x^2 - 6289x + 3E+13$
$R^2 = 0.9432$

$y = 180693x + 2E+13$
$R^2 = 0.925$

Mobile devices and developing economies are a big driver of additional demand
IPv6 deployment incentives (or lack thereof)

- Moving to IPv6 costs real money
  - Training
  - Hardware & Software
  - Reduced reliability
  - Not as well supported as IPv4

- For an exhaustible resource, a transition will not occur until the price of a current resource exceeds the cost of the replacement resource – Hotelling Rule
Hotelling Rule applied to cost of IP addresses

Fictional assumptions: IPv6 is initially 2 times the cost of IPv4, cost of IPv4 increases by 10% per year, cost of IPv6 decreases by 10% per year.
IPv4 Substitutes

- **IPv6 is not a perfect substitute for IPv4**
  - IPv6 costs more and fewer people are “on the network”
  - “Network effect” – Economic concept describing the homogeneity of an adopted protocol

- **NAT**
  - Provides a pretty good substitute for more IPv4 addresses at a small scale
    - Workarounds (STUN, ICE, UPnP, NAT-PMP) have been developed assuming “household” sharing of an IPv4 address
  - Scalability to carrier grade will likely be a challenge
IPv4 Market Dynamics

- IPv4 market is not perfect competition
  - There are significant switching and transfer costs
- Available supply is limited
- Demand continues to grow
Increasing efficiency of IPv4?

Assumptions: 10% growth rate in IP address demand, initial 70% efficiency rate of IPv4, RIRs IPv4 pools depleted in 2012.
# Game Theory in Industry

- Game theory can help us understand industry choices and the consequences of decisions.
- Here we consider a coordination game:
  - Payoffs (profits) are higher when the competitors adopt the same protocol.

<table>
<thead>
<tr>
<th>Competitor B</th>
<th>Competitor A Strategy</th>
<th>Adopt Protocol A</th>
<th>Adopt Protocol B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adopt A</td>
<td>$7, $10</td>
<td>$1, $3</td>
<td></td>
</tr>
<tr>
<td>Adopt B</td>
<td>$4, $1</td>
<td>$8, $12 *</td>
<td></td>
</tr>
</tbody>
</table>

* Adopting Protocol Standard B is a Nash Equilibrium.
IPv6 transition technology confusion
- Too many options (CGN, Dual-stack lite, 6rd, etc)
- Each option has different pros/cons
- Deciding which transition technology to adopt is a “huge” decision: significant capital & operational expense
- No clear path forward

The lack of an adopted protocol standard may be creating a situation where competitors are delaying deployment due to the lack of a “front-runner” standard and risk associated with picking the “wrong” protocol

Does the first adopter have an advantage or a disadvantage?

How does the concept of “economic commitment” help or hurt the industries ability to move forward
Hypotheses #1

- Large scale adoption of IPv6 will not occur until IPv4 exhaustion is complete
  - Application of Hotelling Rule
  - Until the economic cost of IPv4 exceeds the cost of IPv6 most firms will not adopt IPv6
Hypothesis #2

- Transfer prices in various regions will be different due to the different rules, different supply, and different demand
  - Regions with fewer restrictions, lower supply, and highest demand will have the highest prices per IPv4 address
  - Inter-regional transfers could change this
Hypothesis #3

- Rational price of an IPv4 address will be driven by the revenue which can be generated from the resource
  - Some models show prices for “premier” use of IPv4 from $150–$1100 USD per IPv4 address
Economics underpin the transition whether we like it or not

Until the cost of IPv4 exceeds the cost of IPv6 mainstream adoption will not occur

Understanding of how technology, policies, and other factors impact the economics will help us understand how the transition can occur

What can we do as engineers and operators to change the economics landscape to encourage IPv6 adoption?
Thank you

Q&A

Full paper available here: