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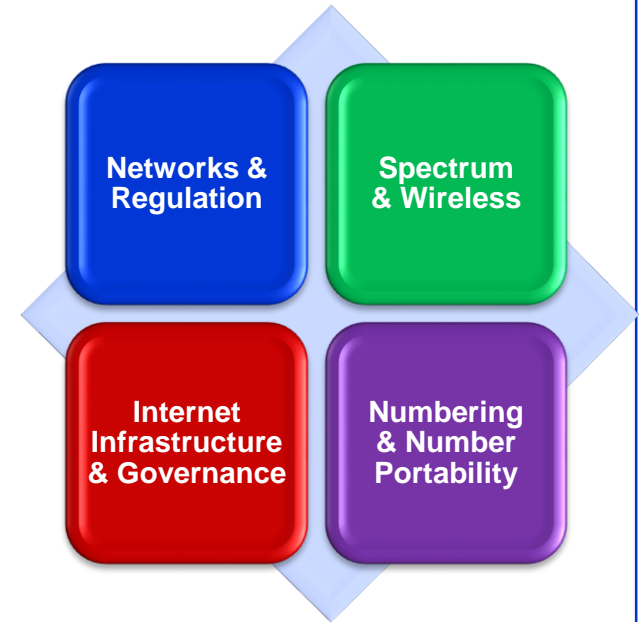
# **Implications of Carrier Grade NAT Technology**

**African Internet Summit  
Mark McFadden  
InterConnect Communications**

# InterConnect Communications

**Established in 1984, specialising in communications regulation and strategy ... 30 years international experience! [www.icc-uk.com](http://www.icc-uk.com)**

- major capacity building projects for national regulators
- development of communications policy, law and regulations
- assisting with introduction and development of regulatory regimes for licencing, access and interconnection, spectrum management
- advising regulators and operators on number portability and number management
- Trusted supplier in developing area of Internet Infrastructure and Governance: ICANN and Ofcom
- 14 years' experience in training provision. 2000 attendees at our renowned series of Master Classes on Telecom and Internet.



# Agenda

- What is the problem?
- Basics of CGN technology – quick overview
- Implications of the implementation of CGN
  - On Internet Users
  - On competition and the marketplace
- What other countries have done
- Findings (in more detail)



# What is Carrier Grade NAT (CGN)?

- Carrier Grade Network Address Translation
- Primarily used in ISP access networks
- Uses fewer public IPv4 addresses to support more subscribers
- Allows ISPs to grow IPv4 subscriber base without requiring an IPv4 address for each subscriber
- Addresses shortage of IPv4 addresses for ISPs
- CGN is also known as; Large Scale NAT (LSN) or NAT444



# The Problem: IPv4 Address Space

- 4 billion addresses (32 bits) exhausted now

Registry	Exhausted	Comment
IANA Central IPv4 Address Pool	3rd February 2011	
APNIC	19th April 2011	Last /8 policy
RIPE NCC	14th September 2012	Last /8 policy
ARIN	Predicted 2014	
LACNIC	Predicted 2014	
AFRINIC	Predicted 2020	

- Demand for IPv4 addresses is still high (peaked at 285 million per year in APNIC before exhaustion)
- UK ISPs can only use existing stock or obtain at most an additional 1024 addresses from RIPE



# Redistribution from IANA Underway

- So few addresses available that IANA instituted its recovered address policy on 22 May
- /11 of recovered addresses delivered to regional internet registries
- This is tiny – about 2 million addresses
  - Doesn't have an effect on the need to move to IPv6
  - Buys a little time for small ISPs in RIRs with little IPv4 address space available



# The Long Term Solution: IPv6

- 340,282,366,920,938,463,463,374,607,431,768,211,456 addresses (128 bits)
- Solves the address shortage problem
- Provides platform for growth and innovation:
  - Internet of Things
  - Sensor networks
  - Multimedia,
  - VoIP and VoD
  - and innovation we cannot yet predict.
- IPv6 brings many other advantages, but first and foremost, it enables expansion of the address space.



# Getting from Here to There

- The transition from IPv4 to IPv6 is not easy
- IPv4 and IPv6 not compatible
- Not just getting connected, content and services need to be available as well
- Costs for both!
  - Costs for creating access to IPv6 networks
  - Costs for copying/moving services to IPv6
- Is there an alternative?



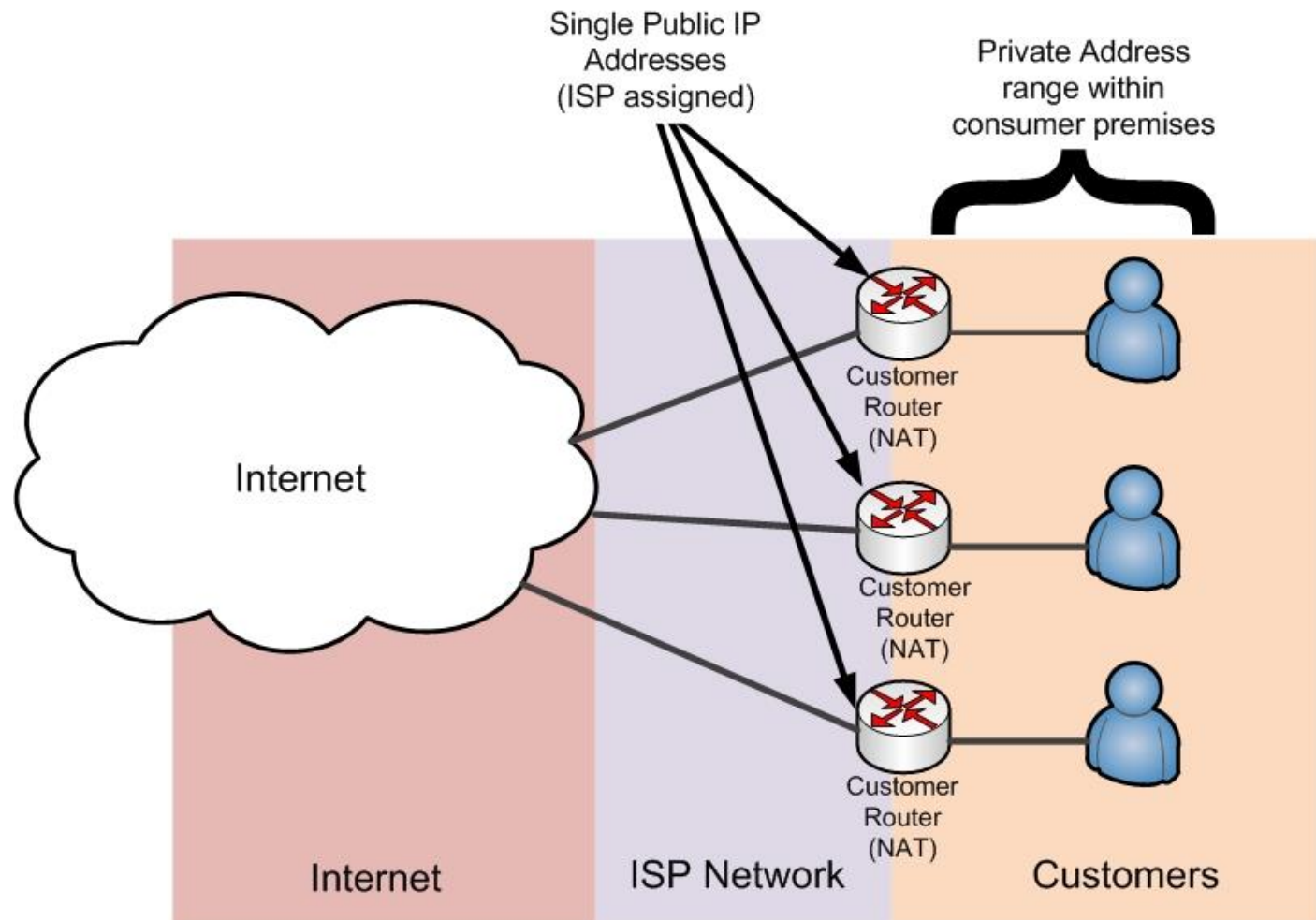


# What are Network Address Translators (NATs)?

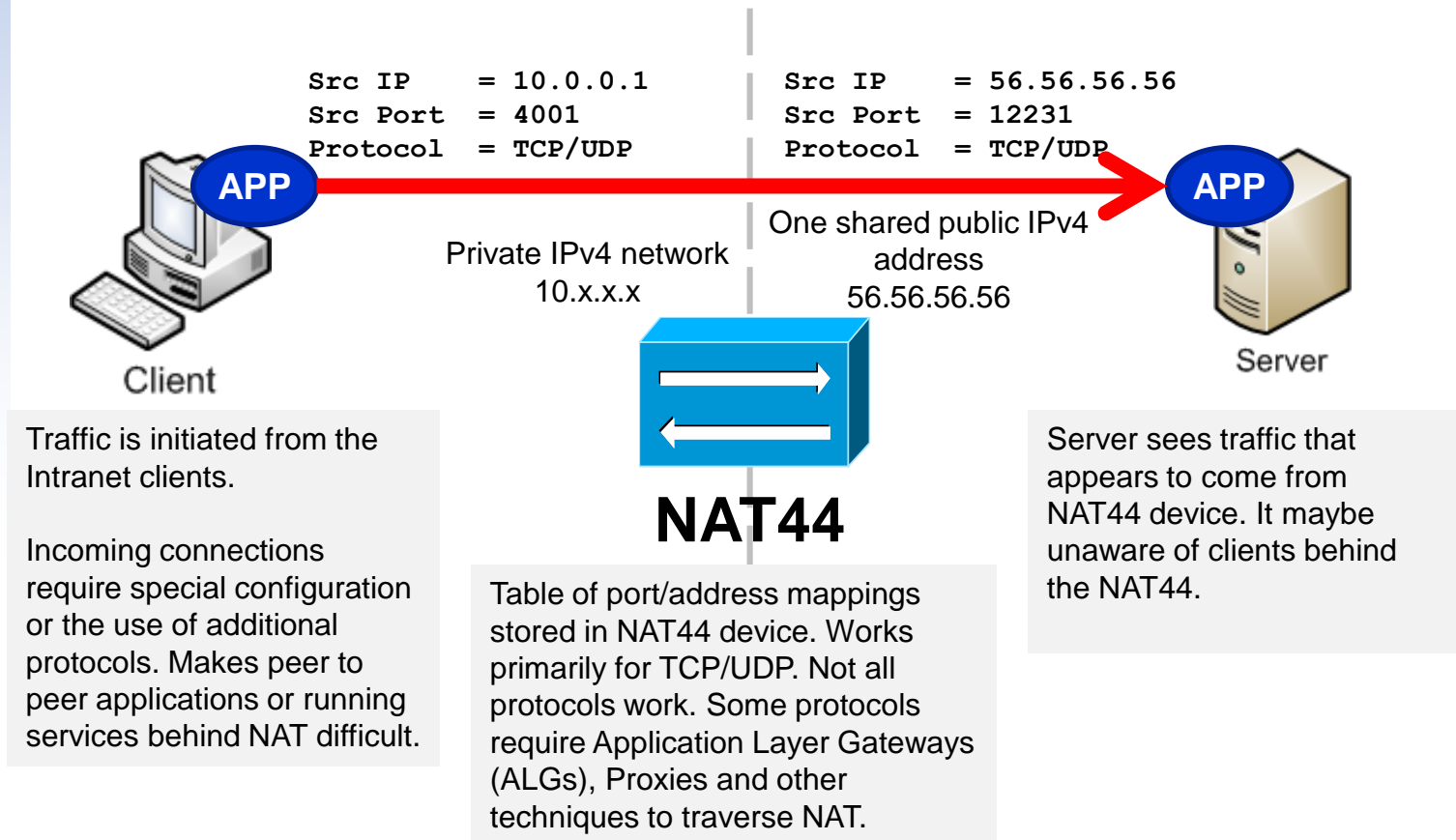
- Deployed in 1990's to preserve IPv4 address space and delay IPv4 address space exhaustion
- Shares one or more IPv4 addresses amongst many devices on a private network (Intranet)
- Ubiquitous especially in consumer broadband
- Creates a boundary between the public Internet and “private” Intranets
- Modifies Internet packets mapping internal addresses to external addresses where possible
- Does not work for all traffic and requires additional configuration/protocols to allow some traffic



# Another View of NATs



# How does NAT Work?

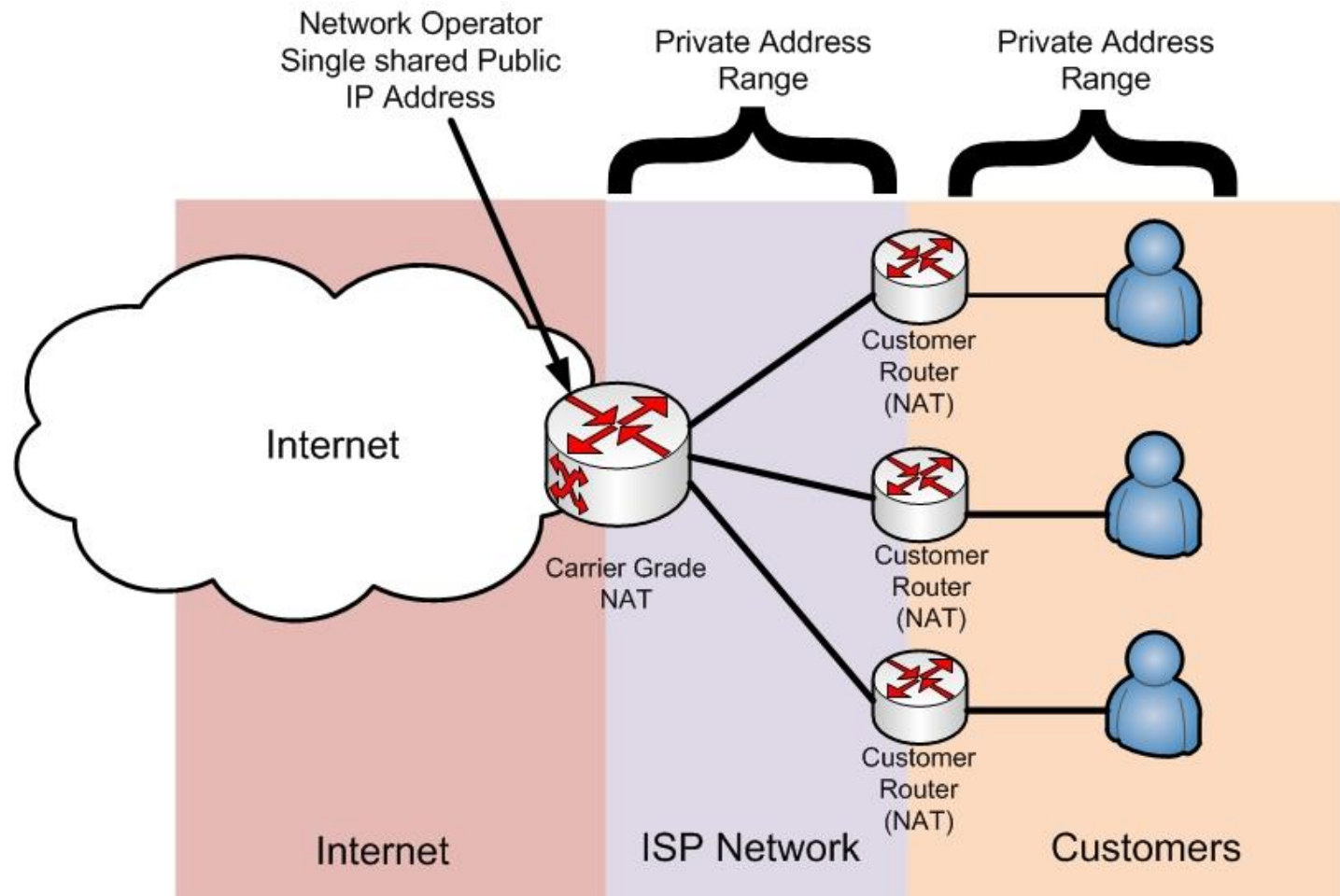


# How CGN Works

- CGN places another layer of NAT in the ISP's access network
- ISP's share IPv4 address amongst many subscribers
- Datagrams are modified more than once; at the subscriber network edge and in the ISP access network
- Moves the public IPv4 address from the subscriber's NAT device to the ISP's CGN device



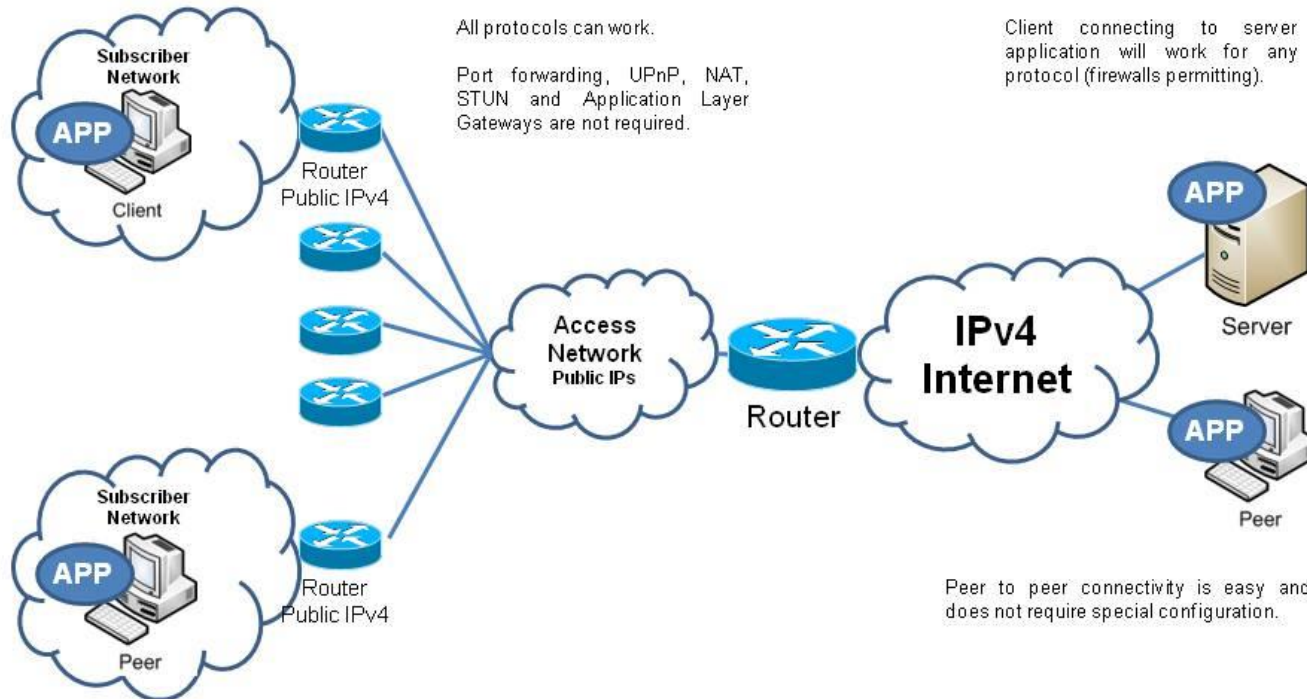
# CGN – A Visual Approach – (1)



# CGN – A Visual Approach – (2)

## Pre NAT

Src IP = 56.56.56.56  
Src Port = 4001  
Protocol = ANY



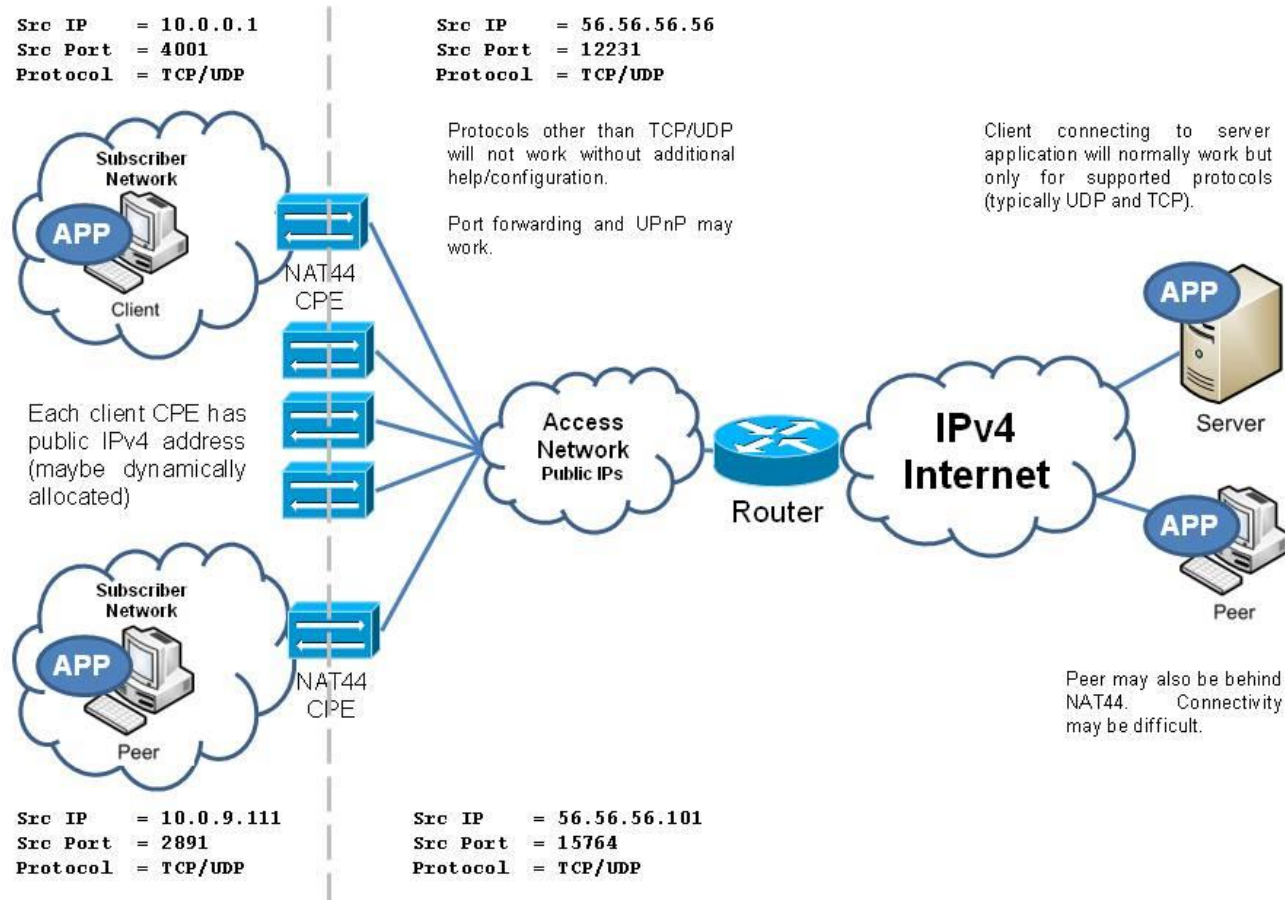
Src IP = 56.56.56.101  
Src Port = 2891  
Protocol = ANY





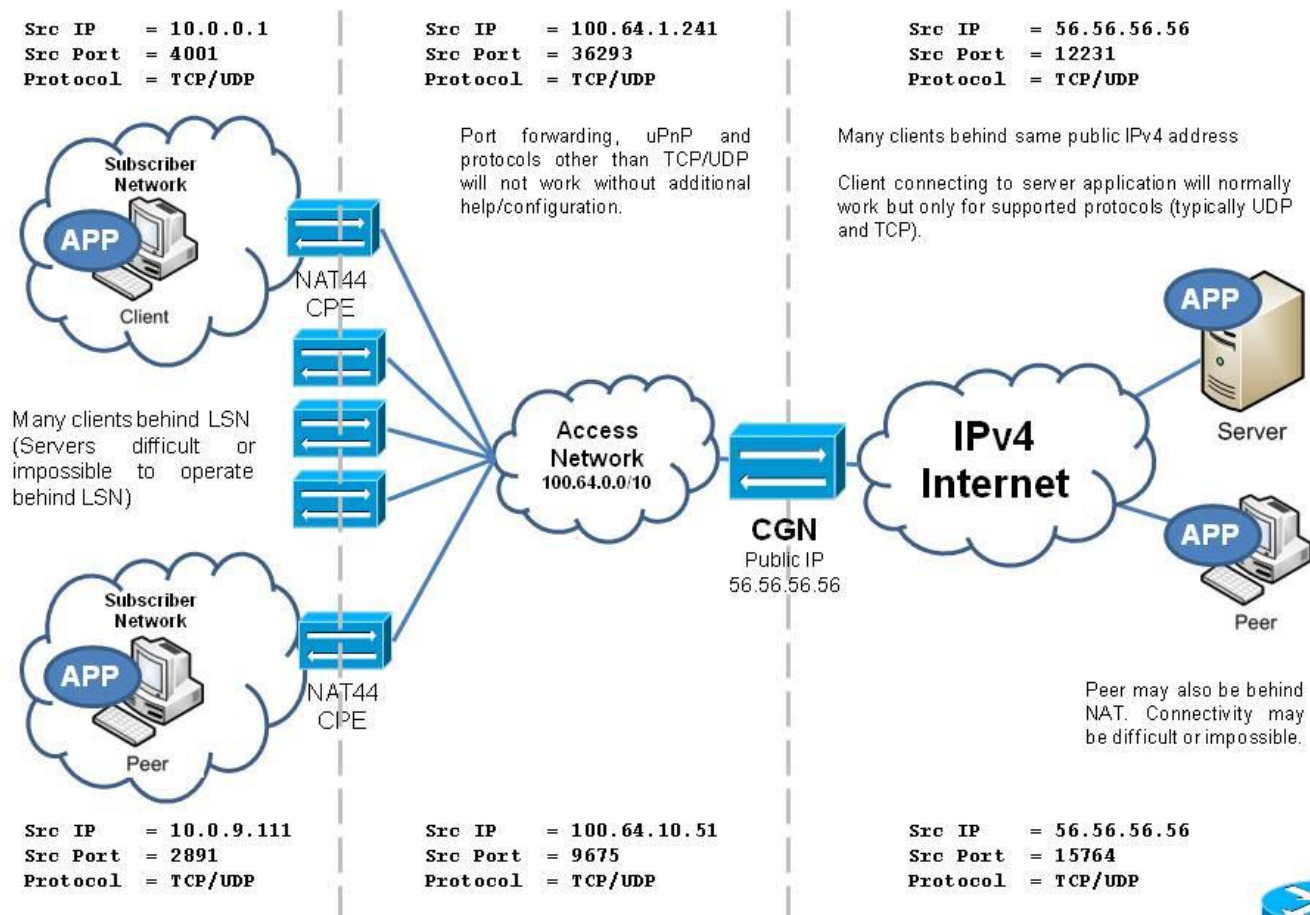
# CGN – A Visual Approach – (3)

## Post NAT



# CGN – A Visual Approach – (4)

## Post CGN





# What is the Motivation for CGN?

- Extend the lifetime of IPv4 by having many users share a common IPv4 address
- “Breathing space” to allow for more time for the eventual transition to IPv6
- Support “traditional” users of basic Internet services
- Support growth while not having to obtain new IPv4 addresses



# Is CGN a Replacement for IPv6?

- No!
- Interviewees during our study didn't intend to avoid IPv6, just deploy at a time more convenient
- CGN seen as an “assistive” technology for transition – not a replacement technology



# How is CGN Likely to be Used?

- ISPs who cannot move quickly to transition to IPv6
- ISPs without a pool of available IPv4 addresses
- An attempt to continue to provide IPv4 services in an environment where there are no more IPv4 addresses
- Mobile networks where there is significant control over devices and applications



# Understanding What CGN Changes

- Key Points:
  - In traditional networks, a consumer gets a single, public IPv4 address to share amongst all the devices in their home
  - In CGN, consumers share their IPv4 address with others
- Address sharing is fundamental to the changes and challenges that CGN bring



# The Challenge of Address Sharing

- Here's an example of what can happen with large scale address sharing
  - Imagine that an ISP shares a single address amongst 5,000 subscribers
  - Imagine a banking site that allows consumers to use the web to do financial tasks
  - When the bank discovers bad online behavior, it figures out the IP address of the machine being used to cause trouble
  - And, then, the bank blocks that IP address from accessing the banking site
  - One bad actor causes an outage for 5,000 customers



# CGN in Mobile Networks

- CGN is used in Mobile Access Networks
- Different environment from traditional consumer broadband
- Consider the end-user environment
  - Few (none!) in-bound connections to a handheld device
  - New applications in the home depend on inbound connections
  - Mobile networks have tight control of the devices that connect
  - Home networks have little control of what gets attached in a consumer network



# Implications of CGN on Users

- Address sharing has implications
  - Can't use the IP address to identify the specific customer
- Any service that relies on an address to identify a customer or service will have challenges
- Many basic Internet services do not require a one-to-one correspondence between users and addresses
- Many newer, advanced applications use the IP address and information gleaned from the address
- There are also difficulties with “in-bound” connections to home networks



# What Things Work with CGN?

- Many basic Internet services/applications work
  - Such as email and basic web browsing work
- Client applications usually work
  - Client as opposed to server or peer to peer applications
- Services that do not depend on IP address/subscriber uniqueness work
- A “basic Internet user” would not be likely to be affected by CGN implementation
  - Good news, because there are lots of them
- Success is dependant on how CGN is deployed and configured





# Why Do Things Break?

- Address sharing causes problems for some software
  - Also techniques to mitigate NAT44 limitations often fail
- Difficulties of supporting in-bound connections causes problems
  - What is port forwarding
- A technical issue: how many ports are available to the consumer?
- Security requirements (for instance, our banking application)



# Standards Work on CGN Implications

- Especially RFC 7021
  - Assessing the Impact of Carrier-Grade NAT on Network Applications
- And also, RFC 6888
  - Common Requirements for Carrier-Grade NATs



# Examples of Things That Break

- Instant Messaging
  - Why?
- Apple FaceTime and Google Talk
  - Why?
- BitTorrent, Peer-to-peer applications
  - Example, Spotify
  - Why?

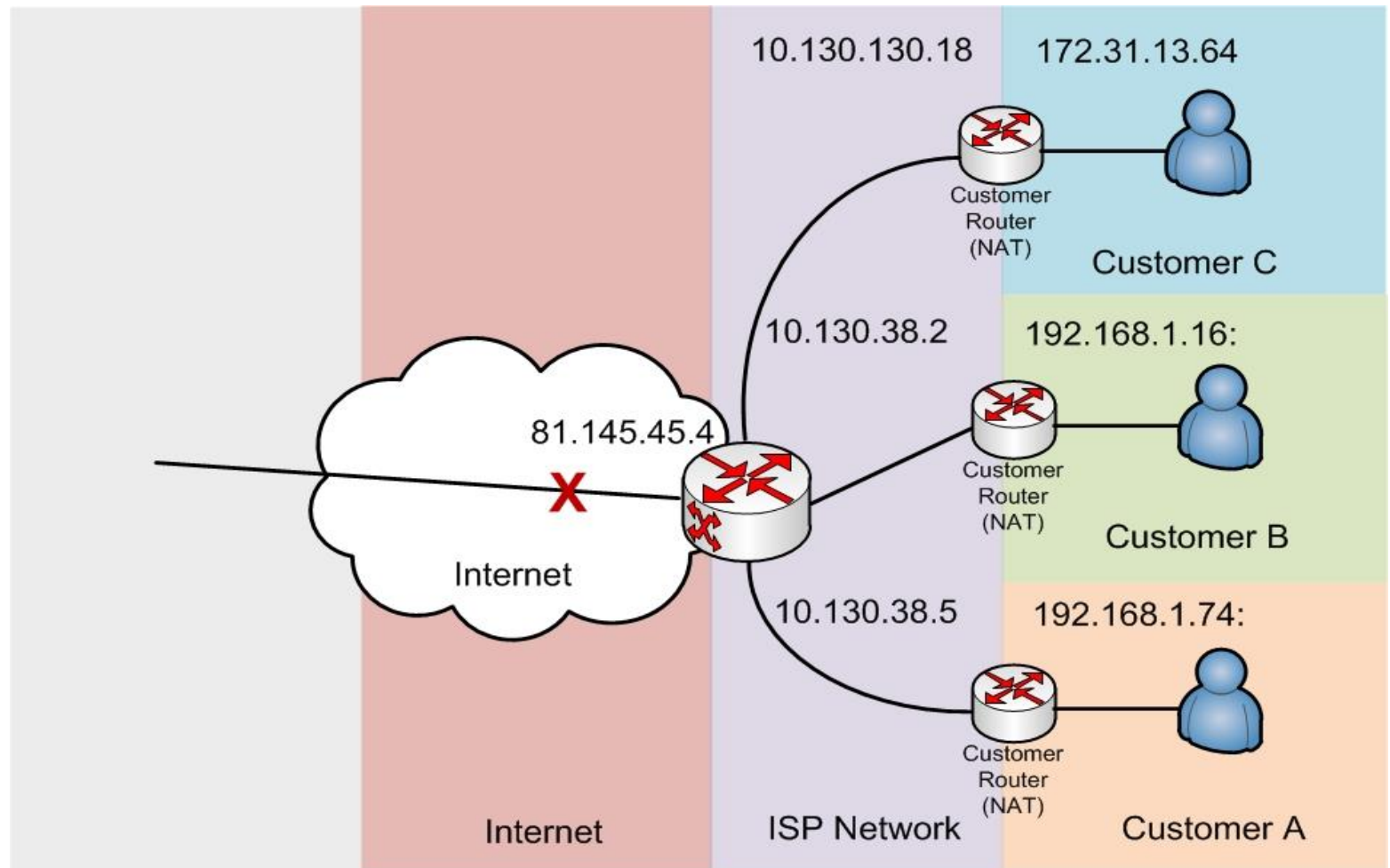


# More Examples

- Media Libraries in the Home
  - Why?
- Remote/Time-shifting of consumer television
  - Why?
- Home security systems and monitoring
  - Why?



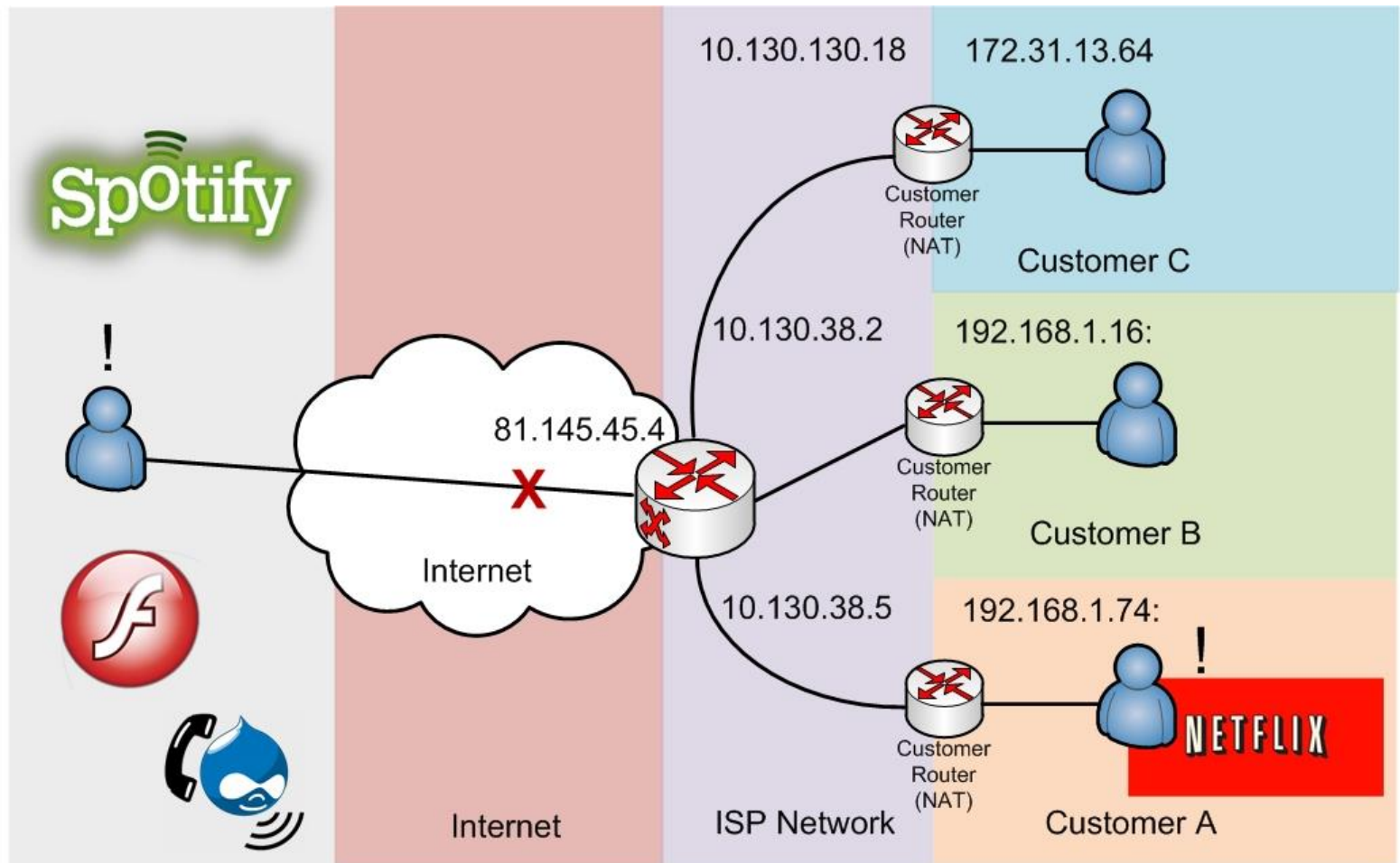
# Problems with Inbound Connections



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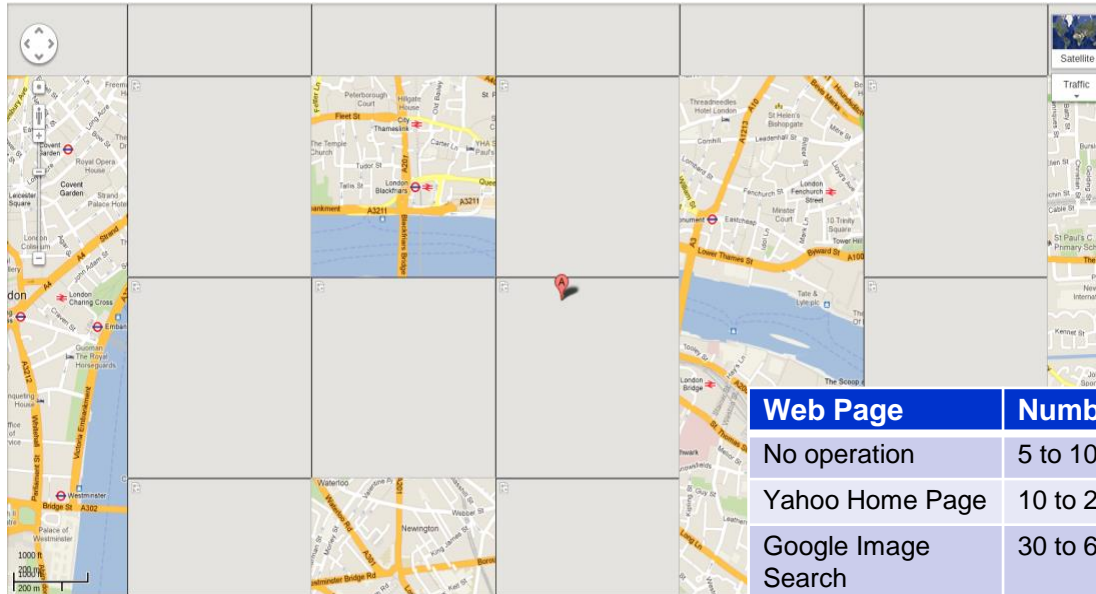
# Problems Inside the CGN's Private Net



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# Example of the Impact of CGN on Number of Sessions



## Google Maps Limited to 10 Sessions

Courtesy Erion Ltd

Web Page	Number of Concurrent Sessions
No operation	5 to 10
Yahoo Home Page	10 to 20
Google Image Search	30 to 60
Google Maps	20 to 50
Nico Nico Douga	50 to 80
OCN Photo Friend	170 to 200
iTunes	230 to 270
iGoogle	80 to 100
Rakuten	50 to 60
Amazon	90
HMV	100
YouTube	90
BitTorrent	700 (Typically hundreds of sessions)



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# Geo-Location and CGNs

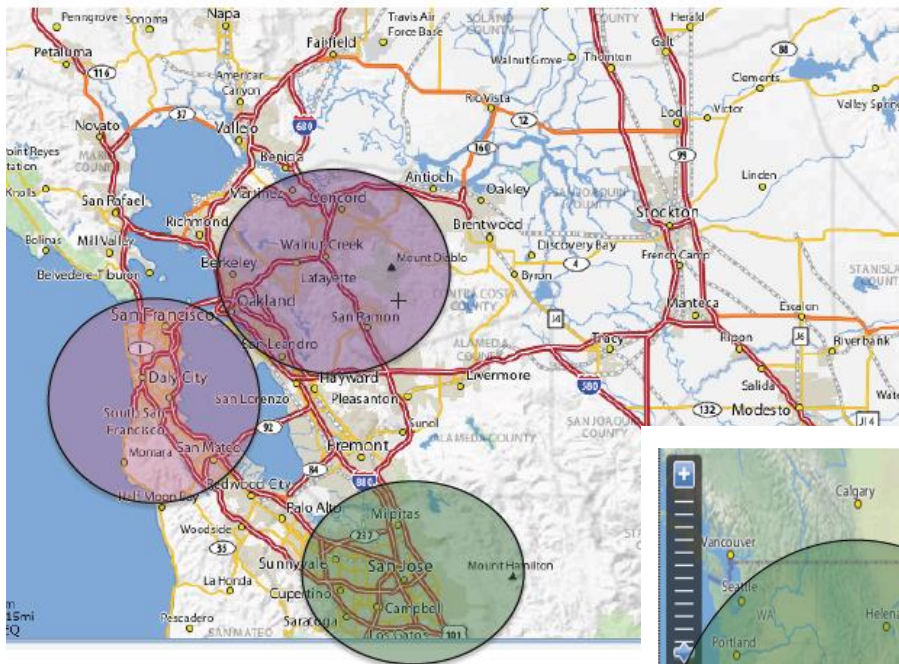
- What is Geo-Location and how does it work?
- Resolution based on the IP address
  - Possible to identify city/town of the subscriber
  - Sometime even better
- Under CGNs the subscribers are pooled and it's harder to find where you are located
- Important not just for customization of web pages
- Geo-Proximity is important as well
  - Especially for gaming performance





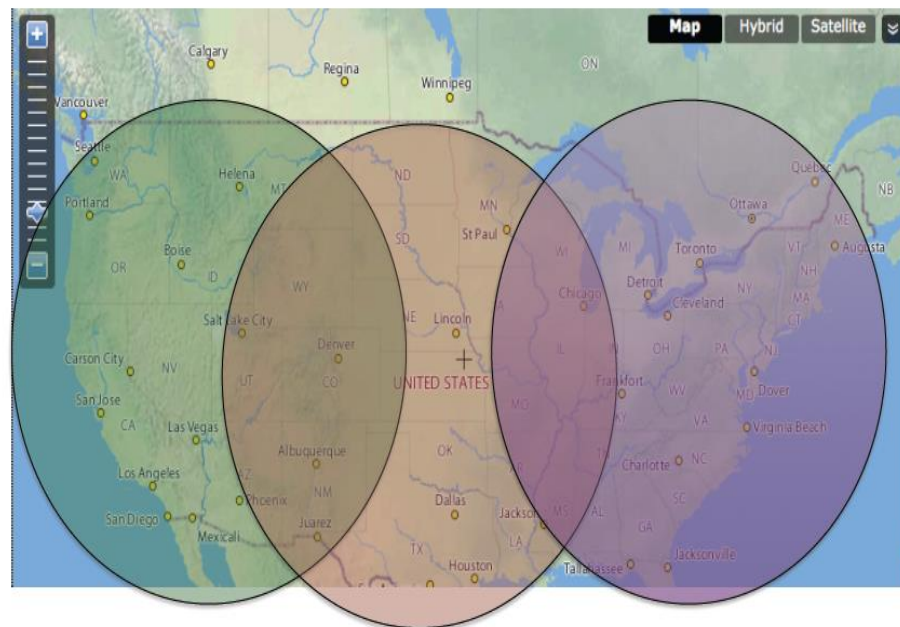
# Example of Impact on Geo-Location

## Best Case



- Courtesy Yahoo!

## Worst Case



# Game Consoles and Gaming

- Features of gaming consoles
- XBOX and PlayStation as examples
- How gaming networks are built
  - How we find people to play games with
- What goes wrong for gamers under CGN
  - Finding each other becomes more difficult
- The difference between the console and the software (game) running on it



# Who is Affected by CGN Implementations

- Consumers who use contemporary and advanced applications
- Consumers who need to gain access to services or computers behind the CGN (for instance, services in the home)
- Software designers who have to design applications that cope with CGN



# Implications of CGN on ISPs

- ISPs appear to benefit from CGN
- However, there are issues for them as well
  - Logging
  - Support
  - Troubleshooting connectivity problems
- Choice of CGN deployment approach and configuration will be crucial



# Logging and CGNs

- Logging requirements can be huge
  - Worst case can make logging impractical
  - Deployment and configuration choices are crucial

Access Network	Service Provider Logging Requirements	Logging Requirements at Destination
Routed	None (fixed record of allocation)	Source IP address
Subscriber CPE with NAT44	None (fixed record of allocation)	Source IP address
Subscriber CPE with NAT44 (Dynamic public IP)	Subscriber dynamic IP address (typically changes daily)	Source IP address + date and timestamp
CGN	Per session: <ul style="list-style-type: none"><li>• Date and time</li><li>• Internal IP address (may be dynamic)</li><li>• Internal source port</li><li>• External CGN source IP address</li><li>• External CGN source port number</li></ul>	Per session: <ul style="list-style-type: none"><li>• Date and time</li><li>• Source IP address</li><li>• Source port number</li></ul>

- Logging requirements at application and content providers are increased regardless



# Support Costs and CGNs

- ISPs agree that support costs increase when CGNs are implemented
- Not able to agree how much those costs increase
- One interviewee:
  - Imagine getting a call where it is difficult to troubleshoot a connectivity problem
  - Have call center staff simply reconfigure the user off the CGN
  - Have that be the default process for fixing difficult connectivity problems



# Beyond the Technical – CGN and Public Policy

- Literature review – what do the academic sources tell us?
- Competition, potential impact on:
  - Existing ISPs and would-be new entrants
  - Applications and online services
  - Customers (business and consumer)
- Privacy, security, enforcement (criminal and intellectual property)
  - Issues arising from blurring of infrastructure and content



# CGN – what are the relevant policy concepts?

- Network formation, basic tenets of Internet
  - Preferential attachment to powerful hubs, and risks (Twitter/RSS)
- End-to-end
  - The dumb core and lack of NAT standards
- Network neutrality
  - Openists, deregulationists, nondiscriminationists and the role of regulators
- Semicommons
  - Interplay of public good and private infrastructure (ISP, consumer)
  - “tragedy of the commons”





# Competition – impact on Internet connectivity

- Benefits – prolong life of IPv4 (ISP and consumer)
- ISPs - New entrants without good IPv4 stocks?
- Consumer:
  - Session hungry apps (consumer vs business systems)
  - New technologies (sensors)
  - 50% of UK households have >3 Internet enabled devices
  - Prices: 2 tier charging; “option swamp”; over-provisioning
- Business customers:
  - Telecommuters, VPN
  - Prices: upselling; increased demand for diminishing pool



# Competition – impact on applications and services

- Far reaching effects (network theory, lack of standards)
- ISP as gatekeeper
  - Potential for discrimination (eg Apple and Google voice)
  - Third party apps break; ISPs' apps don't
  - Payment for access to networks?
  - Low bargaining power of new entrants and innovators
- Consumer:
  - Reduced choice
  - Higher prices
  - Ossify current market positions



# Competition – national competitiveness

- Asian markets and IPv6
- Potential impact of two tier systems:
  - Writing apps for CGN
  - ...or not
- Impact on knowledge economies, and limiting potential for export of services?



# ISPs, CGNs and Law Enforcement

- Subscriber logging and traceback are important law enforcement tools
- Logging becomes much more difficult (can't simply use an IP address anymore) and intrusive
- Analogies with *SABAM* cases (ECJ) and innocent bystanders
- IPv4 addresses as “property”: the market is ahead of RIR policy:
  - Impact on data accuracy and authoritative records
  - Analogy with domain name WHOIS

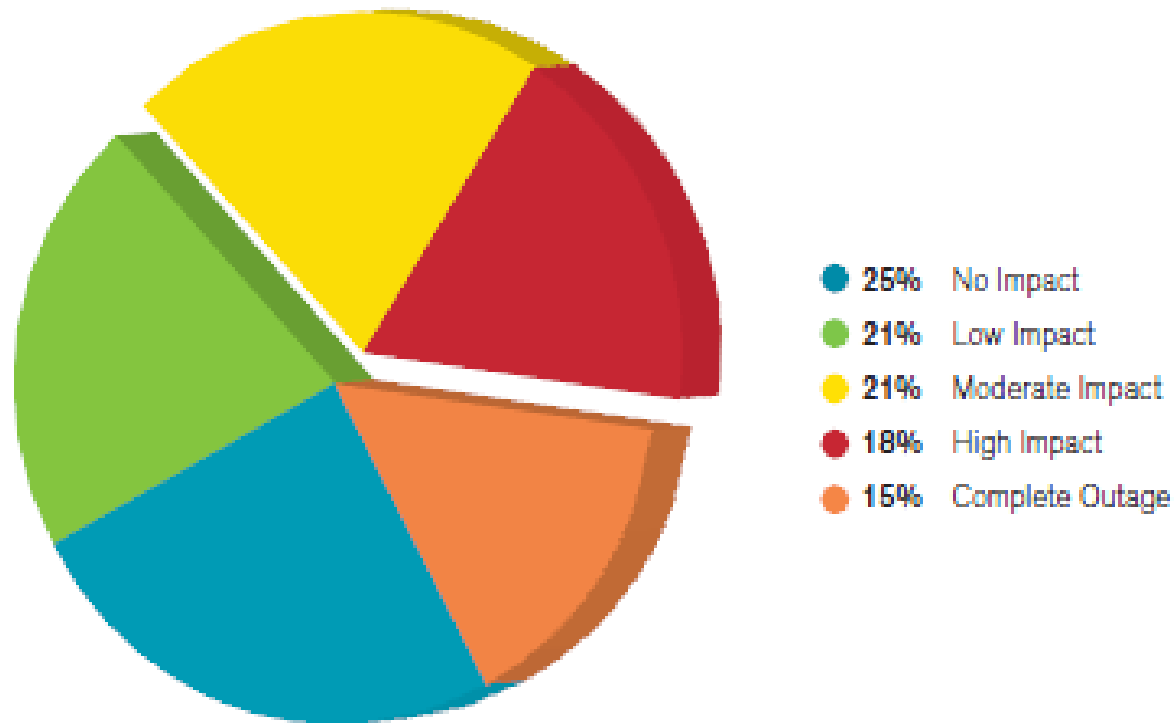


# CGNs and Security

- Introduction of CGN means that there are single points of failure:
  - Targets for attack
  - Identifying sources of spam, malware, bad behaviour
- Standard security features of the Internet do not work in the presence of CGN
- Application designers (eg banks) have to redesign how software and services use identity to security screening
- Emergency services in the absence of geo-location information



# Example Impact of Attacks Against NAT (CGN) Infrastructure



**Survey Results: Breakdown of the 31.1% of Respondents who knew that they had experienced an attack against their CGN infrastructure during the previous 12 months**

Courtesy Arbor Networks



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# Security – impact

- ISPs
  - Data retention costs and complexity: higher
  - But there are benefits which may justify this cost
- Application and service providers
  - Higher costs, but without the benefits
  - Impact of need for tracing of malicious activity to *source*
- Consumers
  - Ever more detailed data processing by providers
  - Increased prices; “option swamp”; poorer service?



# Taking the longer view...

- Erosion of the “permissionless” environment
- Erosion of separation between infrastructure and content:
  - What happens to mere conduit?
  - Gatekeeper to networks – new apps (BitTorrent)
  - The only entity that has the full picture of activity
- Impact on innovation
  - Hard to quantify, takes longer, but you notice when it’s gone
- Tensions between data retention and data protection/human rights
  - Likely to intensify and become more visible.





# The Future: CGN Equipment

- CGN vendors have been through about three generations of equipment
- The CGNs have become more capable as time goes on
- More options for configuring the CGN to adapt to connectivity problems
- Better performance and lower latency
- Larger number of application layer gateways



# The Future: The Tiered Internet

- CGNs have the potential to lead to a tiered Internet
- A “Level of Service” Internet where basic services come at one price and premium services come at another price
- Some CGN vendors advocate that ISPs consider generating revenue this way
- The implication is not just service differentiation based on bandwidth
  - But also in the level of service provided



## . . . And this just in from the Newsroom

- From an interview with UK Deputy Prime Minister Nick Clegg on the home secretary's plan to monitor Internet and Social Media use . . .
- ***“Clegg's only concession during the interview was that the government should look at whether there should be an internet protocol (IP) address for every device, which police and security services have lobbied for.”***

— *The Guardian*, 26 April 2013



# Questions



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