CGN a Driver for IPv6 Adoption

North American IPv6 Task Force April 2017

Dr David Holder CEng FIET MIEEE

Erion

CGN a Driver for IPv6 Adoption

- **Why CGNs are Necessary**
- How CGNs Work
- The Problems with CGN
- CGN as a Driver for IPv6
- Conclusions

Erion

Why IPv6 and CGN?

- IPv4 address pool is empty
- Most regional registrars are out of stock
- No more allocations to existing LIRs/ISPs
- New LIRs/ISPs final /22 only (1024 IPv4 addresses)
- Subscribers still need connectivity to IPv4 services

Please sir can I have some more?

Erion

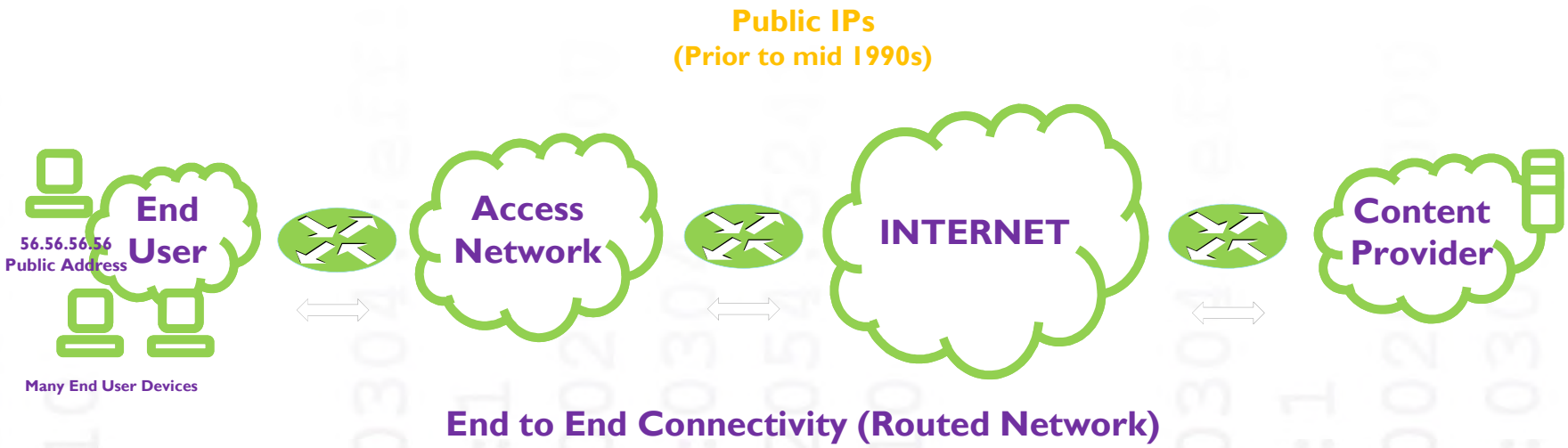
CGN a Driver for IPv6 Adoption

- Why CGNs are Necessary
- **How CGNs Work**
- The Problems with CGN
- CGN as a Driver for IPv6
- Conclusions

Erion

The IPv4 Internet as Designed

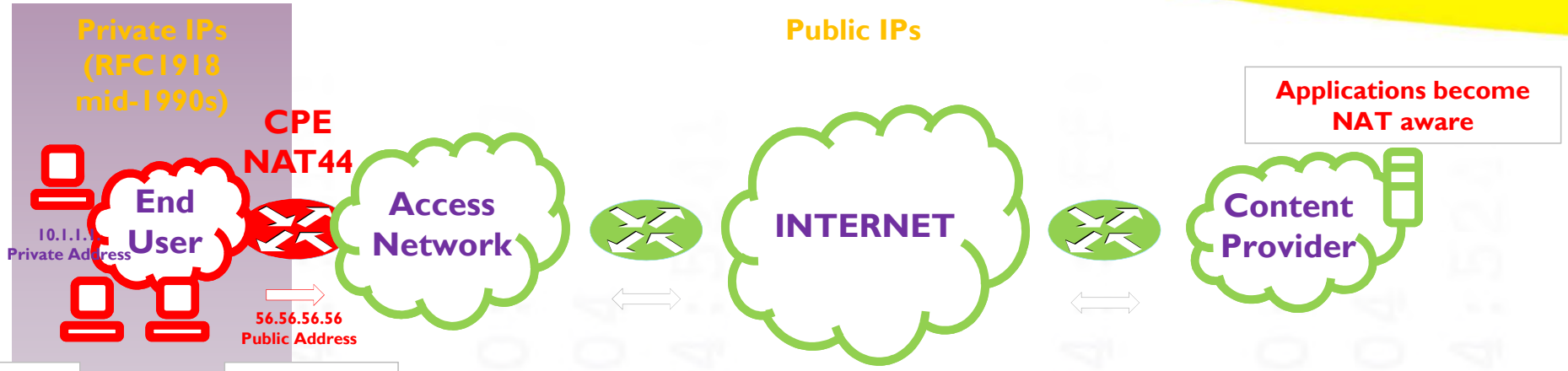
One Public IP = One Node



Erion

IPv4 Internet With NAT44

One Public IP = Many Nodes



- Many End User Devices
- End to End Broken
- Unidirectional
- Not all protocols

- ALGs
- UPnP
- NAT-PMP
- STUN
- TURN
- ICE
- PCP
- Port Forwarding

~~End to End Connectivity~~

Src IP 10.1.1.1 Src Port 4001 Protocol TCP/UDP	Src IP 56.56.56.56 Src Port 12231 Protocol TCP/UDP	Src IP 56.56.56.56 Src Port 12231 Protocol TCP/UDP	Src IP 56.56.56.56 Src Port 12231 Protocol TCP/UDP

Erion

Mitigating the Limitations of NAT44

- Overcoming header mangling
- Example NAT fixes & workarounds
  - Universal Plug and Play (**UPnP**)
  - NAT Port Mapping Protocol (**NAT-PMP**)
  - Port Control Protocol (**PCP**)
  - Session Traversal Utilities for NAT (**STUN**)
  - Interactive Connectivity Establishment (**ICE**)
  - Traversal Using Relays around NAT (**TURN**)
  - Port forwarding
  - Application Layer Gateways (**ALGs**)
  - Proprietary (e.g. Skype)
  - Protocol specific NAT traversal (e.g. IPsec)
- At one point Microsoft had 15 teams working on NAT traversal

Erion

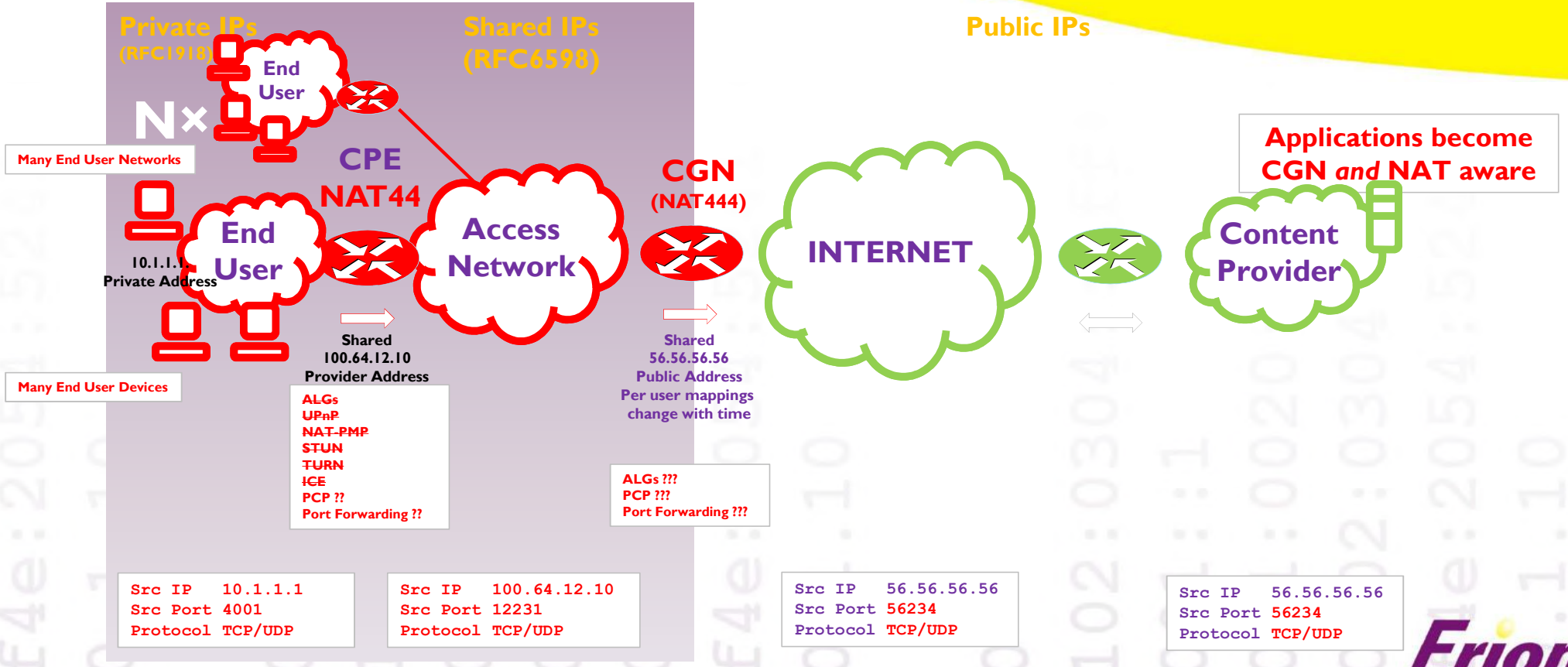
Carrier Grade NAT (CGN)

- More efficient use of IPv4 addresses in service providers
- Provides a breathing space to service providers so they can:
  - Continue to provide and grow IPv4 service
  - Grow their subscriber base
- Additional Network Address Translation in ISP's access network
- Removes public address from end user's router
- Many end users may share same IPv4 address
- Already widely deployed (particularly in mobile)
- A.K.A. Large Scale NAT (LSN) or NAT444

Erion

IPv4 Internet With CGN

One Public IP = Many End Users (and nodes)



Erion

CGN a Driver for IPv6 Adoption

- Why CGNs are Necessary
- How CGNs Work
- **The Problems with CGN**
- CGN as a Driver for IPv6
- Conclusions

Erion

CGN and the Number of Sessions

Scenario	Maximum Number of Sessions (TCP)
Routed	65,536 TCP sessions per **node**
Subscriber CPE with NAT44	65,536 TCP sessions per **end user**
CGN	Maximum set by carrier. Depends on CGN implementation and configuration.
Compression Ratio	
Max 10 end users per IP	= 6,536 TCP sessions **per end user**
Max 100 end users per IP	= 653 TCP sessions **per end user**
Max 1000 end users per IP	= 65 TCP sessions **per end user**

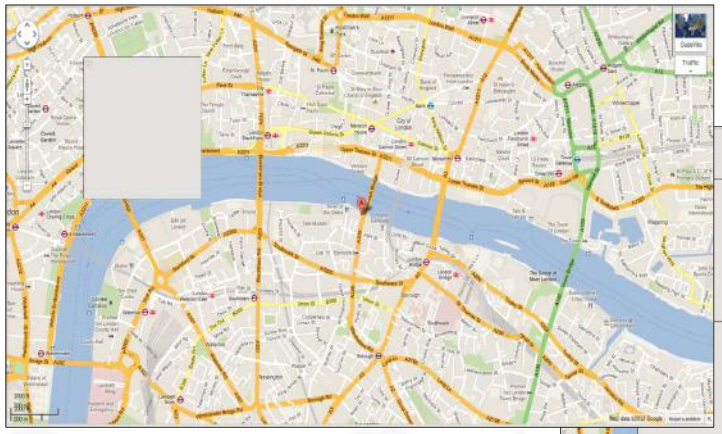
- The more efficiently CGN preserves addresses, the fewer sessions an end user can use

Erion

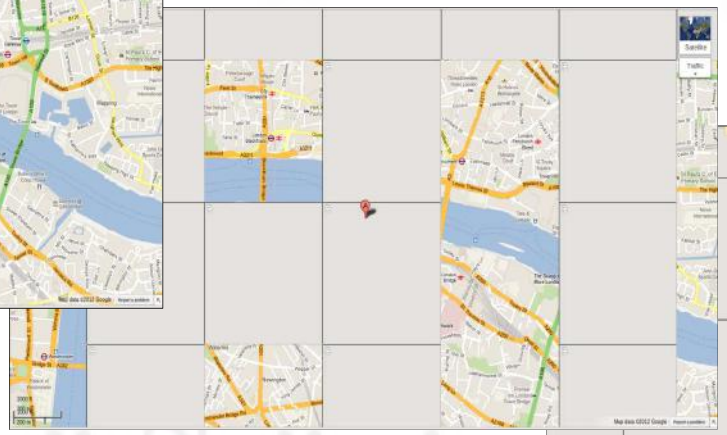
The Impact of CGN Session Limits

- Limit on sessions per subscriber can impact even “basic” web browsing

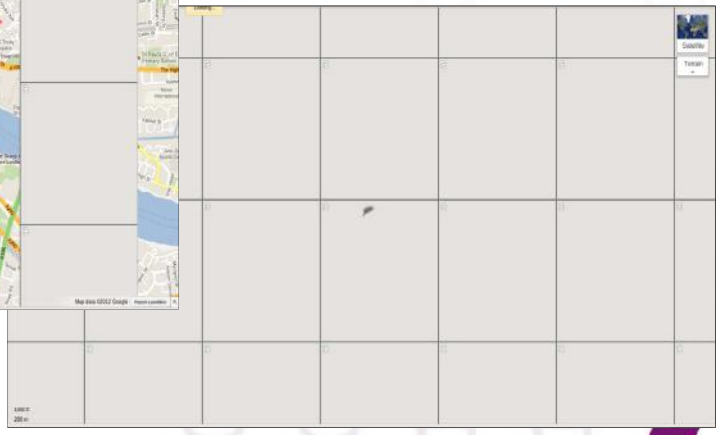
Web Page	Sessions
No operation	5 to 10
Yahoo Home Page	10 to 20
Google Image Search	30 to 60
iTunes	230 to 270
iGoogle	80 to 100
Amazon	90
YouTube	90
BitTorrent	~700



20 Sessions



10 Sessions

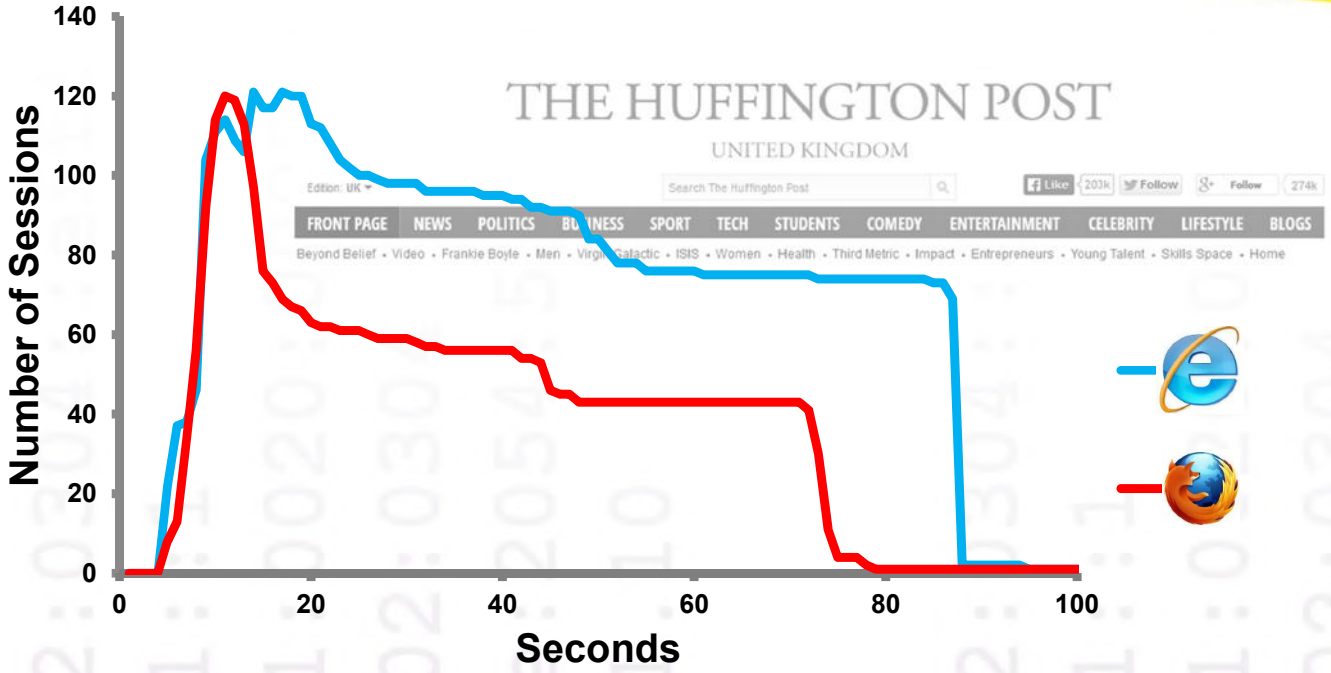


5 Sessions

Erion

CGN Impact on Web Browsing

- Even “simple” web page may use many sessions

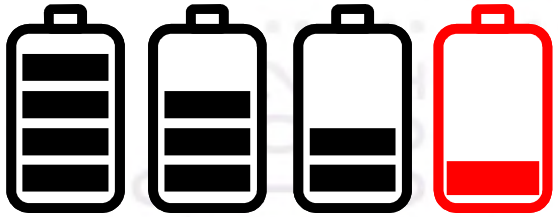


- Typical household uses 33,000 sessions a day

Erion

CGNs and Battery Lifetime

- CGN's remove state for inactive sessions to conserve resources
- Applications must ensure that active sessions are kept open
- Keepalives are used to keep CGN session state active
- Keepalives require an open data connection
- Battery powered wireless devices must power up the radio at the expense of precious battery power to send keepalives
- Frequency of keepalives depends on CGN configuration

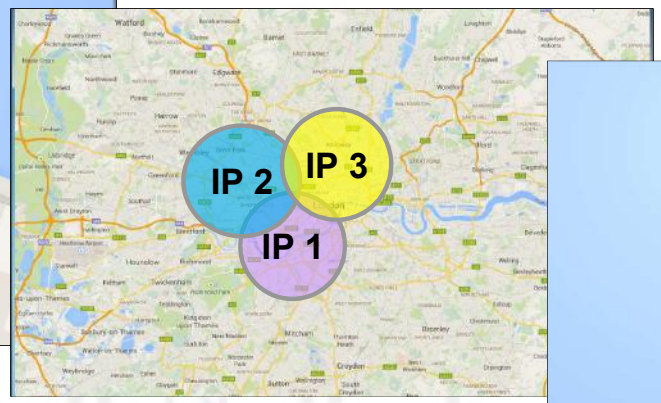


Erion

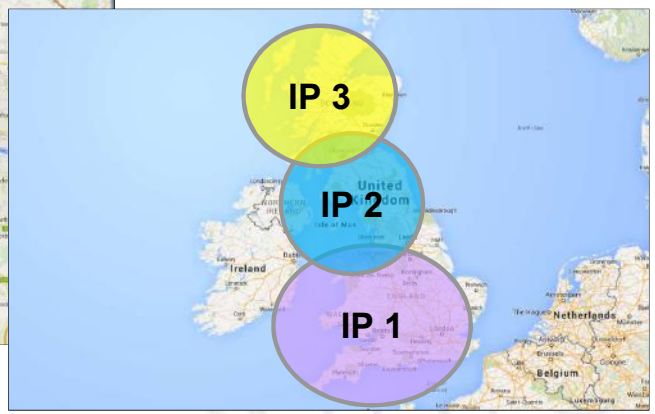
CGN Impact on Geo Location

- CGN reduces the resolution of Geo Location based on IP
- Impacts tailoring adverts for a user's location and techniques to reduce latency in peer to peer applications

Pre CGN



CGN Best Case



CGN Bad Case

Erion

CGN Impact on Analytics

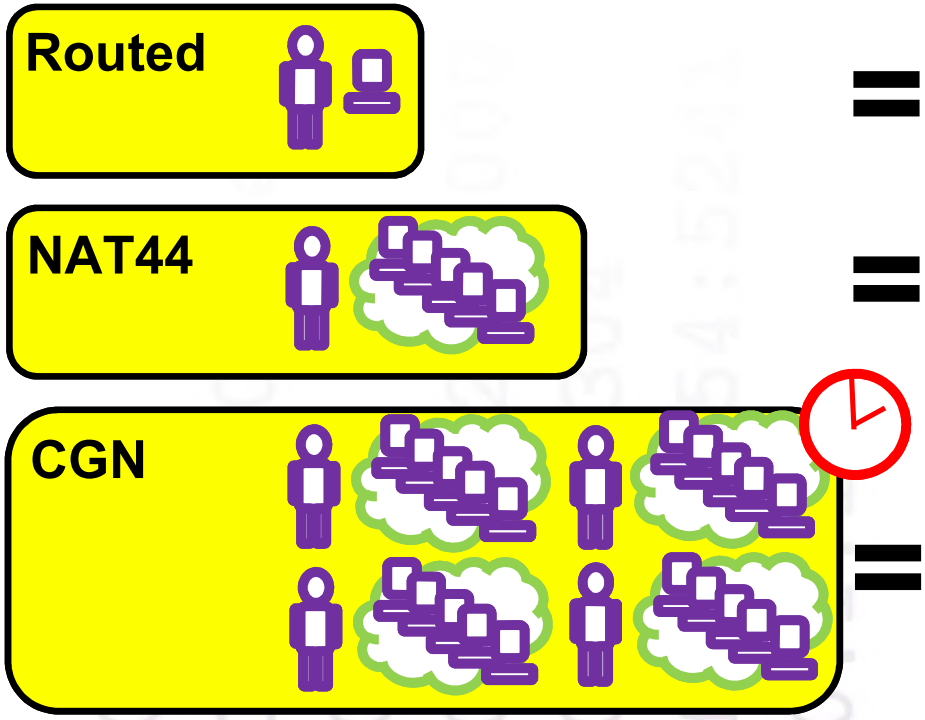
- An address no longer equates to a single end user
- One address may be in use by many users
- User sessions may have many different source addresses
- User to address/port mappings change with time

- You cannot assume one address is in use by one user or that one user's address will remain the same even to the same application or web-site
- Impediment to logging & analytics

Erion

CGN Impact on Analytics

- CGN can make tracking users by IP impractical
- More sophisticated fingerprinting required



= One IP per user node

= One IP per user network & nodes

=
Depending on CGN configuration:
- Different IP for each session
- IPs shared across users
- Port/IP mappings change
- Many users with networks & nodes

Erion

CGN Impact on Logging/Forensics

Access Network	Routed	NAT44	CGN
Service Provider Logging Requirements	None (fixed record of allocation)	None (fixed record of allocation)	Per session (**tens of thousands per user per day**): •Date and time •Internal IP address (may be dynamic) •Internal source port •External CGN source IP address •External CGN source port number
Logging Requirements at Destination	Source IP address	Source IP address (and source port)	Per session (**tens of thousands per user per day**): •Date and time •Source IP address •Source port number

Trivial

Small

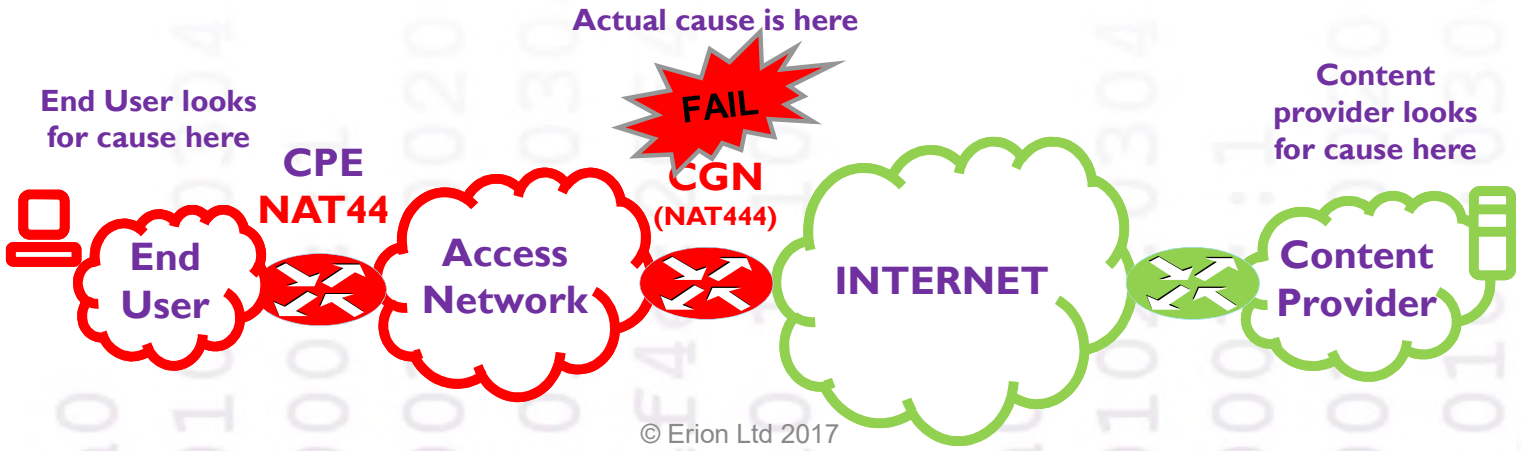
Potential for PBs of logging per million subscribers per year
Plus logging data stream bandwidth will be tens of Mbps

- Difficult (or impossible) to meet lawful intercept obligations
- CGN operator can mitigate with deterministic CGN

Erion

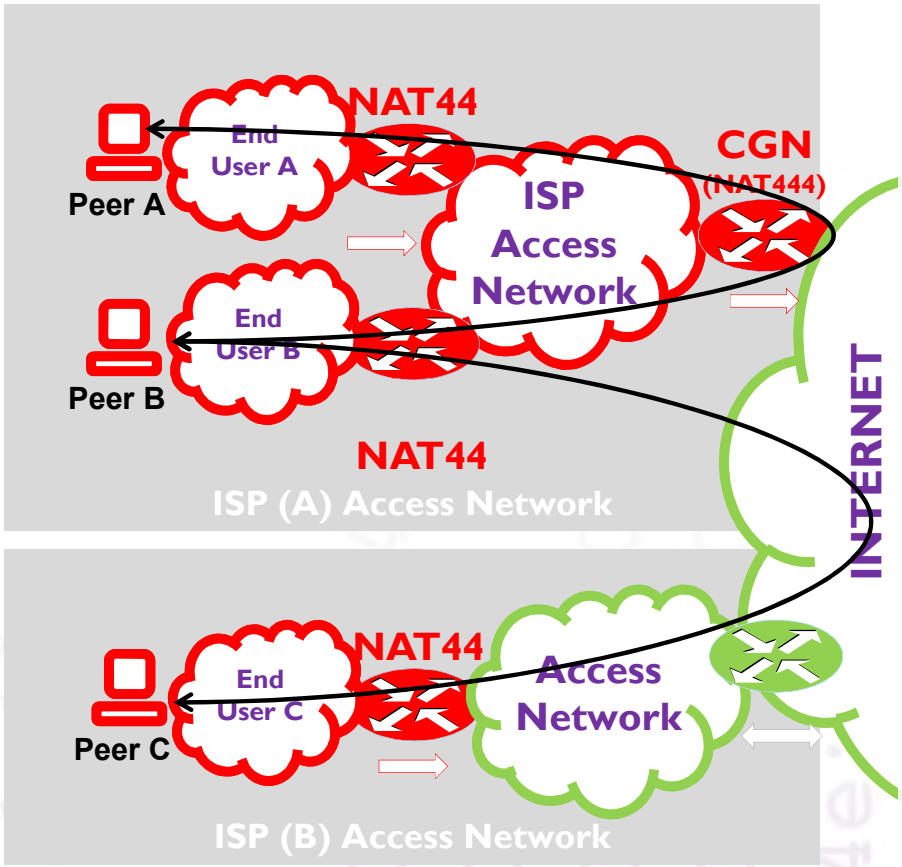
CGN Impact on Support

- CGN obscures the cause of many failures
- CGN failures can be intermittent
- The necessary logging to facilitate debugging may not exist
- End users, application developers, service providers and content providers may have no way of determining that a problem is due to CGN



Erion

CGN and Peer to Peer



- Session state mappings are created for out-going traffic
- P2P peers need knowledge of pre-existing port & address mappings
- Peers behind same CGN will attempt to connect via CGN public address, not directly (hair pinning)

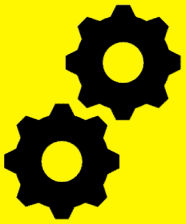
Erion

CGN Impact on Applications

- ***Any*** application can be affected
- **Major** impact on peer to peer applications
- **Major** impact on applications and protocols that depend on NAT traversal techniques
- Variable and intermittent failures
- Some applications deteriorate rather than fail
- Support and debugging can be extremely difficult
- Don't believe every report of success!!

Erion

Impact of CGN Configuration



- There are many CGN configuration options

Option	Minimum Impact	Maximum Impact
Source IP	Same source IP for all sessions (1:1 mapping)	Different source IP for each session (N:1 mapping)
Timeout	Long timeouts for mappings	Short timeouts for mappings
Session Limit	Unlimited number of sessions per user (increased vulnerability to DDoS)	Very limited number of sessions per user
App Support	Extensive support for NAT44 mitigation (ALGs, UPnP pass-through, PCP etc)	No support for applications
Area	Geographical area limited	Large geographical area

- Options have a significant impact on the effect of CGN

Erion

Other CGN Problems

- **CGN impact on forensics and privacy**
  - Conflict between regional legal intercept and privacy laws
- **CGN impact on blacklisting and net reputation**
  - Users behind CGN share an IP address with other subscribers
  - One subscriber's reputation can be affect by the behaviour of another subscriber
- **CGN impact on net neutrality**
  - CGN service is different from non-CGN service
  - Session information can be used to provide different levels of service

Erion

CGN Impact on IPv6

- IPv6 transition mechanisms fail with CGN
- Even Teredo can fail
  - Teredo is designed specifically to traverse NAT44
- If ISP implements CGN without providing IPv6 service then end users will not have the option of accessing IPv6 using transition mechanisms
- This has knock-on effect for existing applications that utilise IPv6 transition mechanisms for connectivity through NAT44

Erion

Overcoming the Problems of CGN

- Most common NAT44 traversal solutions fail with CGN
  - UPnP, NAT-PMP, STUN, ICE, TURN, port forwarding, proprietary (e.g. Skype)
- One or two may work with ISP intervention
- Partial solution is the Port Control Protocol (PCP)
  - End users use PCP to control path through CGN
  - Must be enabled by ISP and must be available in end user's CPE
  - Many ISPs have said that they are reluctant to enable PCP
- IPv6 avoids all of this

Erion

Myths and Reality

- CGN is widely deployed
- CGN will become even more widespread
- End users and content providers have no control
- CGN has all the problems of NAT44 plus more
- CGN issues are difficult to detect
- Lots of things will work fine; edge cases will not
- Will this affect you? – probably. Will you know the cause is CGN? – not necessarily

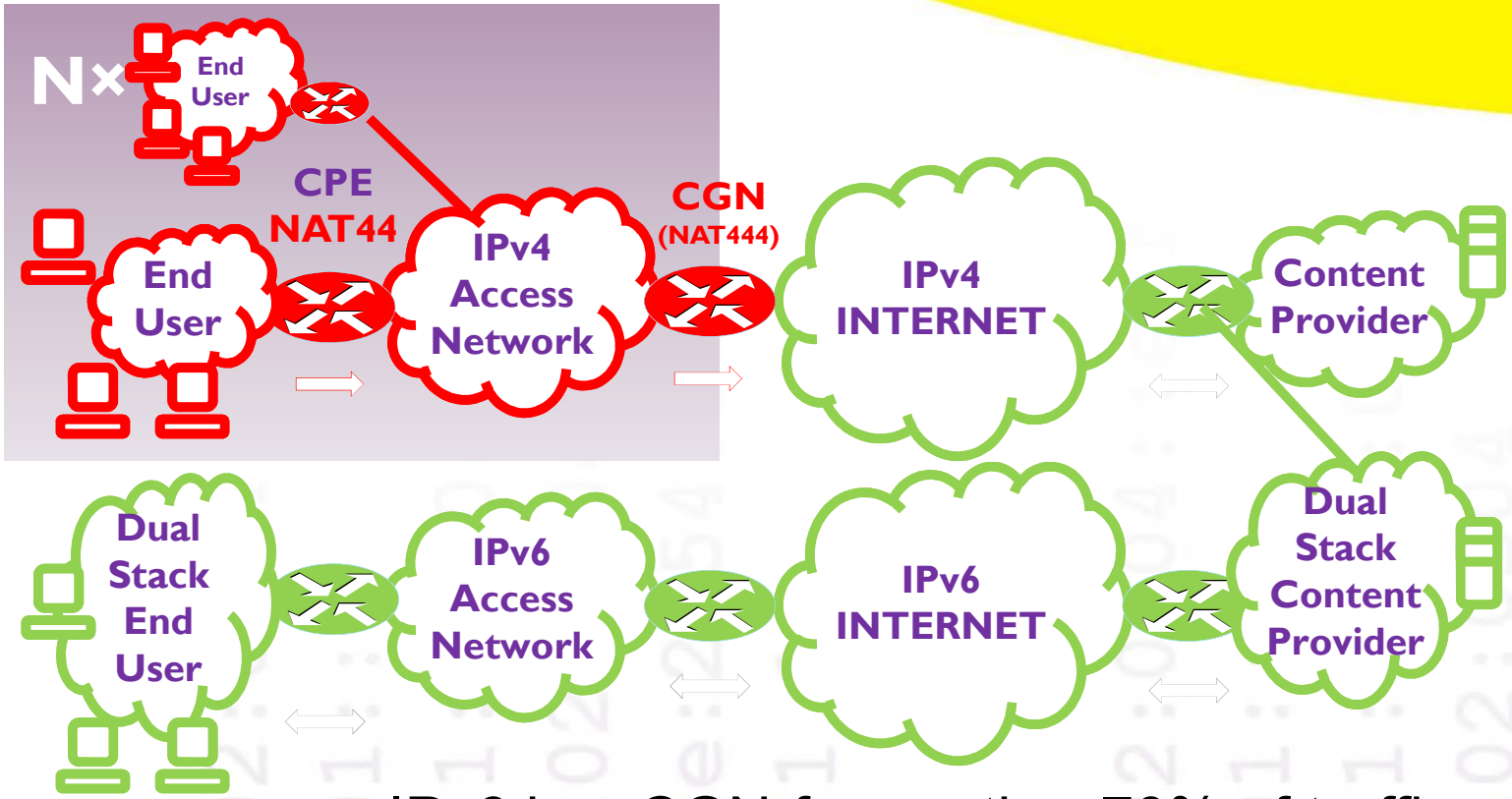
Erion

CGN a Driver for IPv6 Adoption

- Why CGNs are Necessary
- How CGNs Work
- The Problems with CGN
- **CGN as a Driver for IPv6**
- Conclusions

Erion

IPv6 the Solution to CGN



IPv6 is a CGN-free path > 70% of traffic

Erion

CGN as a Driver for IPv6

- IPv6 avoids all of the problems of CGN

- CGN problems have clear business implications
- The impact of CGN can be appreciated by management
- It is impossible to ensure that CGN has no impact
- You cannot guarantee that CGN is not in the path

- IPv6 is the *only* practical CGN-bypass solution
- IPv6 is beneficial for *all* actors

Erion

IPv6 Benefits for All

- **End users**
  - Provides an alternative to a CGN path (for >70% of typical traffic)
  - Provides a public IPv6 address for services and P2P apps
- **Service providers**
  - Providing an IPv6 path for end users behind CGN is best practice
  - Mitigates CGN impact on all players including customers
  - Reduces load on CGN and further preserves IPv4 addresses
- **Content and application providers**
  - Maximum mitigation of CGN impact on users and customers
  - Minimise the cost and difficulty of supporting CGN users/customers

- Minimises CGN impact for IPv6 paths

Erion

Conclusions

- CGNs are widely deployed
  - You have little (if any) control over the impact of CGNs
  - CGN challenges: performance, reliability, logging, analytics, functionality, impact on applications
  - CGNs have created second*-class internet citizens
  - Whatever you do you must prepare for CGN in applications, services, administration and support
- CGNs are driving IPv6 adoption
  - IPv6 provides a solution to the problems of CGN
  - CGNs have already driven IPv6 deployment particularly in ISPs
  - IPv6 users are first-class internet citizens again
  - The business impact of CGNs is meaningful to management

Erion

* “third”?

Further Information

- CGN
  - Report on the Implications of Carrier Grade Network Address Translators, Ofcom, David Holder et al
- Erion
  - IPv6 Services
    - http://www.erion.co.uk/ipv6.html
  - IPv6 Blog
    - http://www.ipv6consultancy.com/ipv6blog
  - IPv6 Training
    - http://www.ipv6training.com
  - IPv6 Consultancy
    - http://www.ipv6consultancy.com

Erion

Profile: David Holder

- CEO and Chief Consultant Erion Ltd
- Author of numerous reports and whitepapers
- Chairman of IPv6 Task Force Scotland
- Regular speaker on IPv6
- Extensive experience of IPv6 spanning over 19 years

Erion

A Brief History of NAT & CGN