EzIP Enhanced Internet

Presentation to

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2018 February __
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- **The IPv4 based Internet went through phenomenal growth during the last few decades.**
- **However, the future is dampened primarily due to the exhaustion of the assignable public address pool.**
- **The challenge is to resolve this issue with minimum perturbation to the deployed equipment and the established operation.**
- **After extensive study, the only solution seemed to be moving on to IPv6. However, IPv6 has not been delivering what was expected.**
- **Apparently, IPv6 is not a superset of IPv4, nor capable of encapsulating the latter. This handicap of not being able to achieve a smooth transition is a major surprise for a protocol that was set out to replace the one being heavily depended upon by everyone in daily use.**
- **Currently, the Dual-Stack approach has to be adopted to allow both to coexist.**
- **A recent review of the IPv4 suggests the possibility for a fresh alternative.**
- **The implication of the Phoenix icon will be apparent after this presentation.**

Outline

A. Why this Proposal

B. What is the Solution

C. Optimum Approach

D. Technical Considerations

E. Enhanced Internet Architecture

F. Summary

- **This presentation will focus on an overview of system level concepts and analysis. Afterwards, we can explore related topics of interest.**
- **We will outline the problem parameters, how did we see the light at the end of a very long tunnel by describing an everyday fact that inspired our effort,**
- **and then present the proposed solution.**
- **Related technical components are examined to validate the realizability and the feasibility.**
- **With significant expansion of assignable public IP address as the result of the proposed scheme, not only the IPv4 address shortage has been resolved, but also an even larger reserve pool is created, ready to support additional digital networks.**
- **These findings transcend the current Internet fabric to be a true worldwide communications backbone with expanded capabilities and improved performances.**

A. Why this proposal

- IPv4 address pool almost depleted
- IPv6 deployment sluggish
  https://ams-ix.net/technical/statistics/sflow-stats/ether-type
  https://stats.labs.apnic.net/ipv6
- ISPs in developed regions showing no interest in end-to-end connectivity
- Disadvantaged regions concerned with
  - technical challenge, and
  - financial burden of going to IPv6
- IPv4 and IPv6 coexist on Dual-Stack for quite sometime to come

- **Although the IPv4 address pool depletion has been publicized for a long time, no quantitative analysis is available about why and how it happened.**
- **Based on up-to-date statistics, IPv6 is carrying only about 2% of the Internet traffic and hardly any country has more than 50% devices ready with IPv6. The former is updated every 15 minutes. The latter is averaged across 7 (or more) days.**
- **These seem to correlate with the general impression that with limited IP addresses, ISPs in developed regions enjoy maintaining control over the subscribers, while disadvantaged regions are handicapped from rolling out essential services.**
- **Regardless of these manifestations, not able to uniquely identify every terminal in the Internet is a fundamental handicap preventing the IPv4 from becoming a full-fledged communication protocol.**
- **Under the Dual-Stack environment, we should apply whatever technology that may be appropriate to either.**
- **Today, we will focus on what could be done to improve the IPv4 environment.**

Boundary Conditions

- **Demand - By Year 2020:**
  - **Population: 7.6B (Billion) -** World Statistics
  - **IoT Devices: 50B -** Average 6.6 IoTs / Person (Assumption)

  https://www.cisco.com/c/dam/en_us/about/ac79/docs/innov/IoT_IBSG_0411FINAL.pdf
- **Supply - IPv4 Address Pool Size: About 4B (from 256 x 256 x 256 x256, or 4 Octets with 8 Bits each)**
- **Address Demand estimated to be 13 times over the Supply**
- **Actual usable IPv4 pool much smaller than 4B due to historical allocation practices**

  http://www.iana.org/assignments/ipv4-address-space/ipv4-address-space.xhtml

- **To start this analysis, we need to know the quantitative conditions that we are facing with.**
- **Prediction by Cisco whitepaper - 2011 April**
- **The world population has already hit this mark (2017 October).**
- **The IoT forecast (6.6 IoTs/person) probably is a bit aggressive. However, it is better to have a larger demand number as the target in budgetary planning. Note that this is the only assumption in this presentation.**
- **Basically, the IPv4 address capacity is at best only one 13th of the projected number of worldwide IoTs by Year 2020.**
- **In reality, the ratio is even worse, because many of the IPv4 addresses have not been properly utilized, as may be seen in the IPv4 Address Space Registry.**
- **In the past, there have been various techniques proposed to mitigate this address shortage issue, with some relief but no true success.**

B. What is the solution

- **Expand assignable IPv4 public address pool:**
  - **Introduce Semi-Public Router (SPR) - A simple IPv4 compatible new router**
  - **Insert an SPR inline, between an Internet Edge Router (ER) and the private premises it serves, to expand the assignable public addresses**
  - **Designate a block of addresses within the IPv4 pool for SPR to use**

(Refer to example - next slide)

- **Today, we will address this topic directly.**
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- **Since SPRs provide public routing functions, the effective assignable IPv4 public address pool is expanded.**
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- **To maintain the address format compatibility, a subset of IPv4 addresses need be reserved from the main pool to be used by the SPR operation.**
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- **The last step may sound contradictory, since the IPv4 pool is officially depleted. However, arithmetically removing a subset of finite elements, say 10, from a relatively large set, say 4B, has minuscule effect to the overall set. On the other hand, upon applying such a subset geometrically to multiply the remaining set, the effective overall number of elements is expanded accordingly to become 40B (minus 10 x 10 to be exact).**
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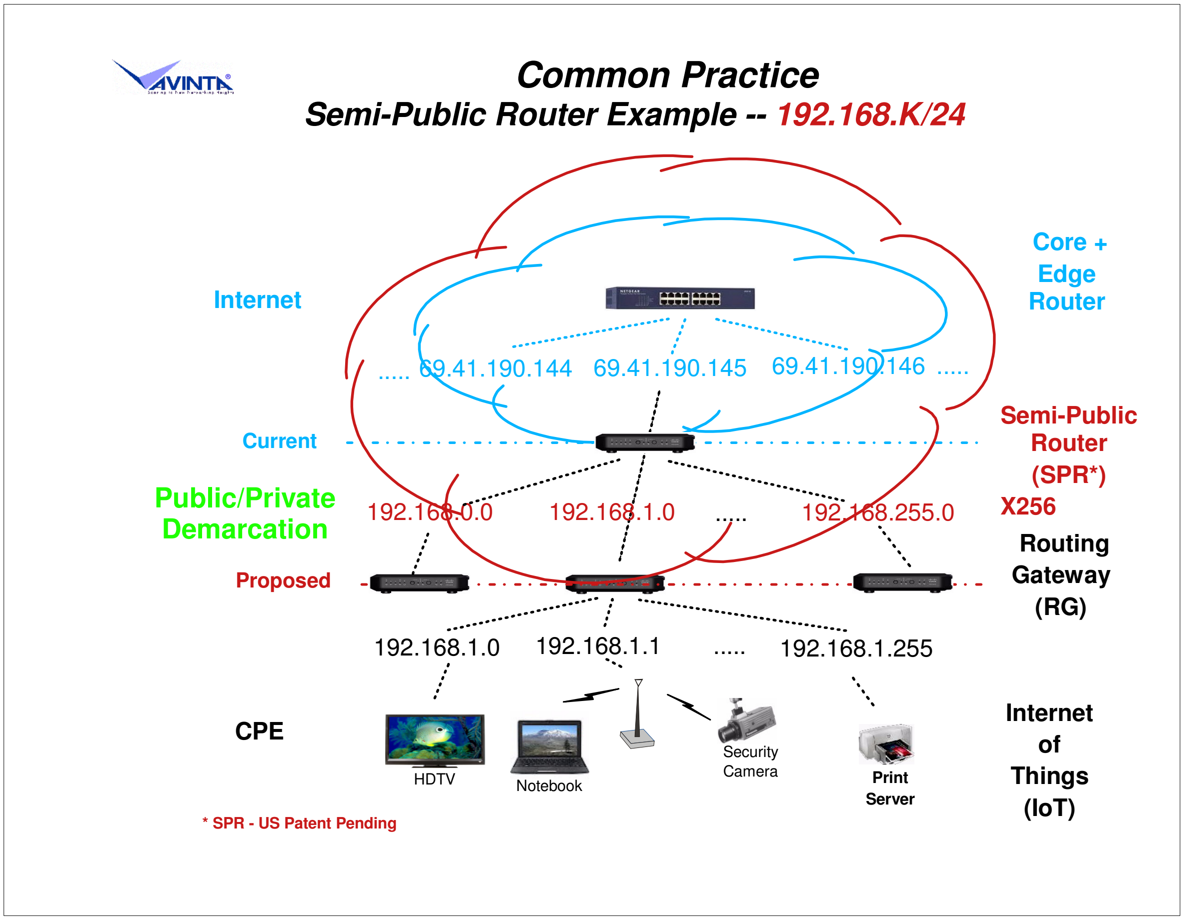
- **As it turns out, a generally overlooked block of reserved IPv4 addresses that is much larger than 10 is available for this process, creating a surprisingly huge resource that opens up a lot of possibilities.**



- Although everyday Residential Gateways (RGs) are allocated with private network address block 192.168/16, most RGs are actually operating with the 192.168.K/24 convention, whereby K is a parameter between 0 and 255, with most common values being 0, 1, 2, 10, etc. preset in the factory. Under this condition, each private network is restricted to 256 addresses, available from the fourth octet.
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- A group of RGs like the above, each with a different K value, may operate from the same public IPv4 address without conflict. The router that serves these 256 RGs is one of the basic SPRs.
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- Since the RGs have not changed nor moved, the conventional demarcation line remains where it has been from a subscriber's perspective.
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- Applying this configuration to every one of the 4B IPv4 addresses, we can expand the Internet by 256 times to get the total of about 1000B assignable IPv4 compatible public addresses. The supply becomes 20 times of the 50B IoTs by Year 2020. Or, even the spare pool is now 19 times of the demand.
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- This finding encouraged us to look further for similar and perhaps better resources. For simplicity in discussion, we created a name, EzIP (phonetic for Easy IPv4) for representing various aspects of these efforts.

C. Optimum Approach

- **The 240/4 block:**
  - **From 240.0.0.0 through 255.255.255.255 whose first four bits are all "1", totaling 256M addresses**
  - **Reserved for "Future use" since 1981-09: Not routable - neither publicly nor privately**
  - **Offers the potential of multiplying each current IPv4 public address by 256M times, yet**
  - **Does not impact existing public and private networks, nor IoTs**

(Refer to Optimum EzIP example - next slide)

- **The other two private network address blocks, 172.16/12 and 10/8, with capacity of 1M and 16M, respectively, commonly used by government agencies, large businesses and institutions, etc., each can similarly support the SPR to multiply the IPv4 pool by 256 fold for a total of 768 times.**
- **However, there are tradeoffs in utilizing this basic scheme:**
  - **As one octet is reallocated for extending the public address, the size of the corresponding private network is reduced accordingly to one 256th.**
  - **With this scheme, the assignable address pool could be multiplied by a factor of over 17M with full end-to-end connectivity, by sacrificing all three private networks that have certain desirable properties, such as anti-intrusion.**
  - **Since these address blocks have been used privately without coordination for many years, however, it will be difficult to reclaim any portion of them for universal application, except perhaps only the 192.168.K/16 block. Although the 256 multiplication factor providing 19 times of spare is more than enough, it is not prominent enough, in view of the IPv6 capacity.**
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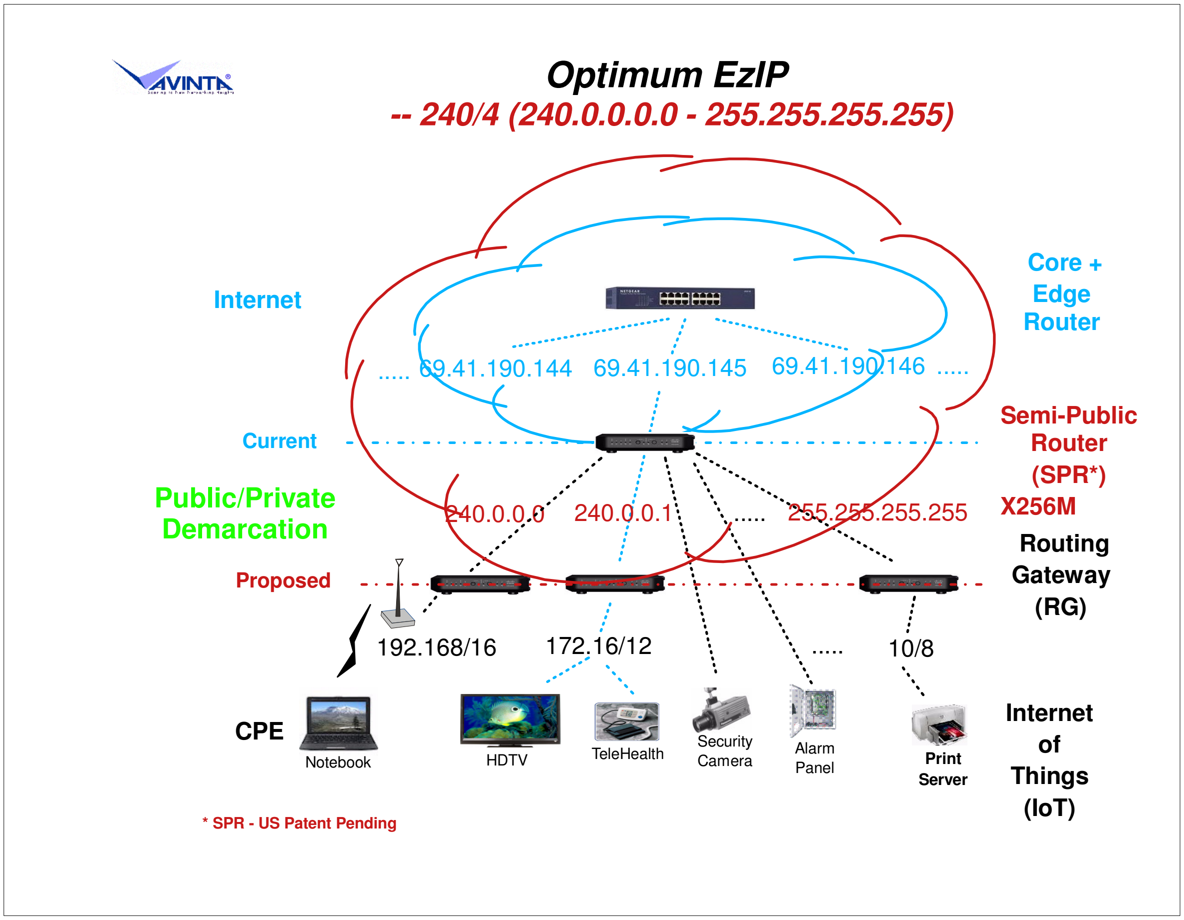
- **The better candidate is the 240/4 block (from 240/8 to 255/8). This block has been reserved for a long time and appears to be under used at this juncture. Utilizing this block opens up a big new frontier.**



- **Let's start with a basic Internet system diagram the same as the previous one, except showing a 172.16/12 private network.**
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- **Making use of the 240/4 block, each SPR may expand each IPv4 public address to a publicly assignable pool of 256M addresses.**
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- **The Demarcation line will similarly stay where it is currently.**
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- **The 4B Internet address pool is now expanded 256M times to be 1000MB, or 20M times of the projected IoT demand (50B) by Year 2020.**
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- **Since 256M (0.256B) addresses have to be reserved from the overall IPv4 pool first, the more accurate calculation of the above would be about 0.959BB ((4 - 0.256)B x 0.256B), or 959MB.**
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- **To properly implement the EzIP scheme, we need to be sure that the parameters utilized are all available and there is a reliable mechanism to transport such information between SPRs stealthily through the current Internet (without disturbing the established facility). This is analogous to the PSTN regarding the digitally encoded audio signals between dial-up modems as if they were part of a voice call.**

D. Technical Considerations

- **APNIC: Requested to redesignate 240/4 block for "Private Use" (But, 2. Caveats of Use)**
  https://tools.ietf.org/html/draft-wilson-class-e-02
- **RFC 791: Defined Option mechanism in the IP Header (Figure 9)**
  https://tools.ietf.org/html/rfc791
- **Over a dozen of Option numbers available**
  http://www.iana.org/assignments/ip-parameters/ip-parameters.xhtml
  https://tools.ietf.org/html/rfc6814

(Refer to Enhanced Internet Architecture example - next slide)

- **Address Resource: IETF Draft by APNIC (2008 - Page 2, Section 2) proposed to redesignate the 240/4 block as the fourth private network address block, yet identified that many deployed private network routers would reject the 240/4 block as "experimental". Since the SPR is new, there is no conflict.**
- **Transport Mechanism: IETF RFC791 (1981 - Page 38, Figure 9) defined the Option mechanism together with EOOL (End of Operation List) and NOP (No-Operation) Option codes for carrying flexible length information, such as 240/4 addresses, as IP header payload.**
- **Payload Identifier: One or more Option Numbers are needed to represent the 240/4 address information conveyed by the Option word(s) that follows. Out of 32 possible Numbers, most have been used. Fortunately, RFC6814 (2012 - Page 4) deprecated nine Option Numbers that were assigned to earlier experiments. So that the EzIP will not create another resource exhaustion situation.**
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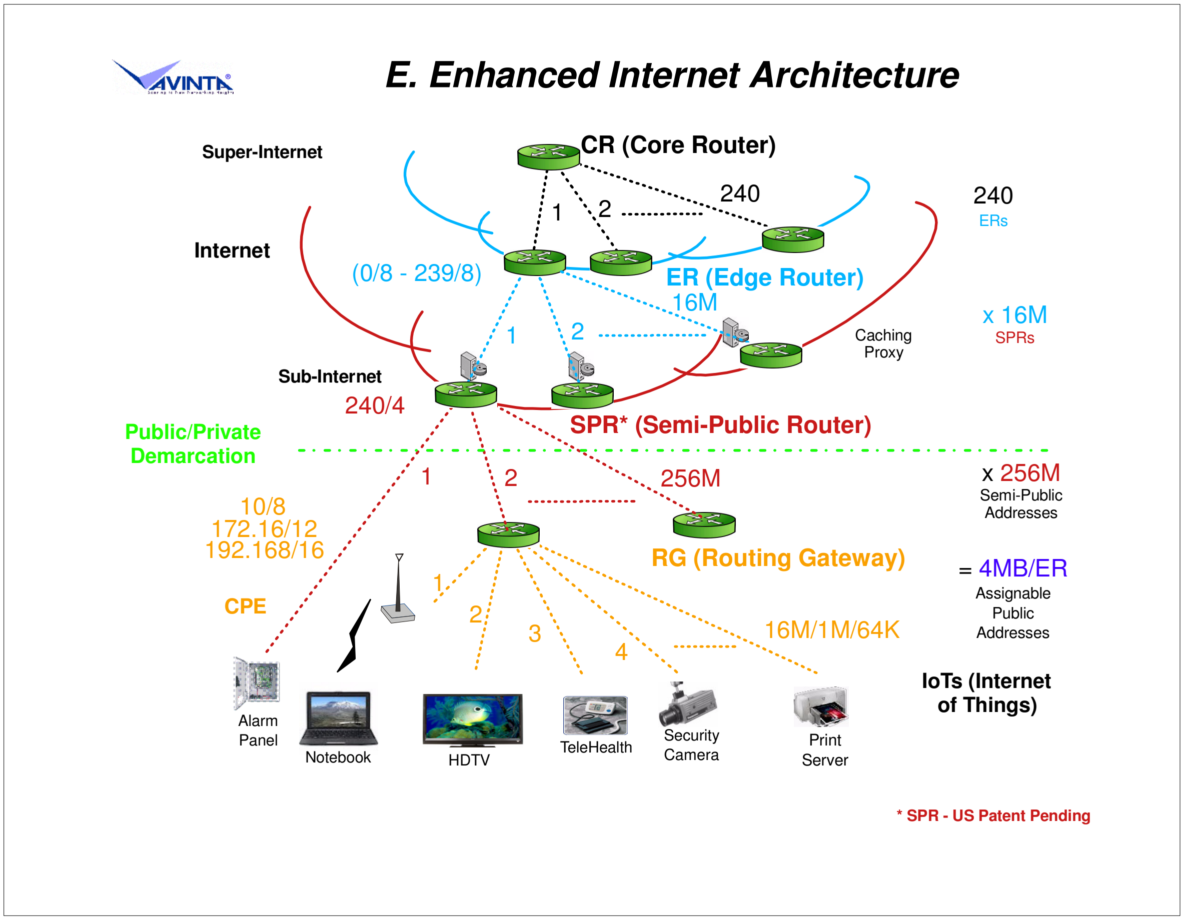
- **In brief recap, each SPR can support a region with 39M (256M / 6.6) people that is larger than the most populous city (Tokyo Metro.: 33M). Consequently, the majority of countries can now be served through just one IPv4 public address. Even the most populous countries, China and India need fewer than 40 each.**
- **This releases a lot of IPv4 public addresses to enable systematically planning a renewed and more capable Internet configuration.**



- With the 240/4 block reserved as the extension address pool, 240 blocks (0/8 - 239/8) of addresses remain for ERs to manage 16M SPRs each. In turn, each SPR handles 256M addresses. Under each ER, the 4MB (16M x 256M) addresses are 80K times of 50B. This is sufficient for every person, on the average, to own over half a million (6.6 x 80K) IoTs, even without using private networks.
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- Employing a Caching Proxy as the gateway for an SPR to access its ER and to mirror the databank from the Cloud will not only improve the data service performance, but also transparently convert between the public IPv4 address used by the ER and the EzIP address used by the SPR. Each SPR can now operate autonomously as a sub-Internet, as well as the information backup for one another, even the central databank, in case of operation difficulties.
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- Intra-SPR packets, being the majority traffic, may use just the 240/4 address in the basic IP header (without the public address overhead), much like calls among PABX (more technically accurate, CENTREX - "CENTRal office EXchange") stations using only extension numbers without prefixing the PABX's public line number assigned by the PSTN.
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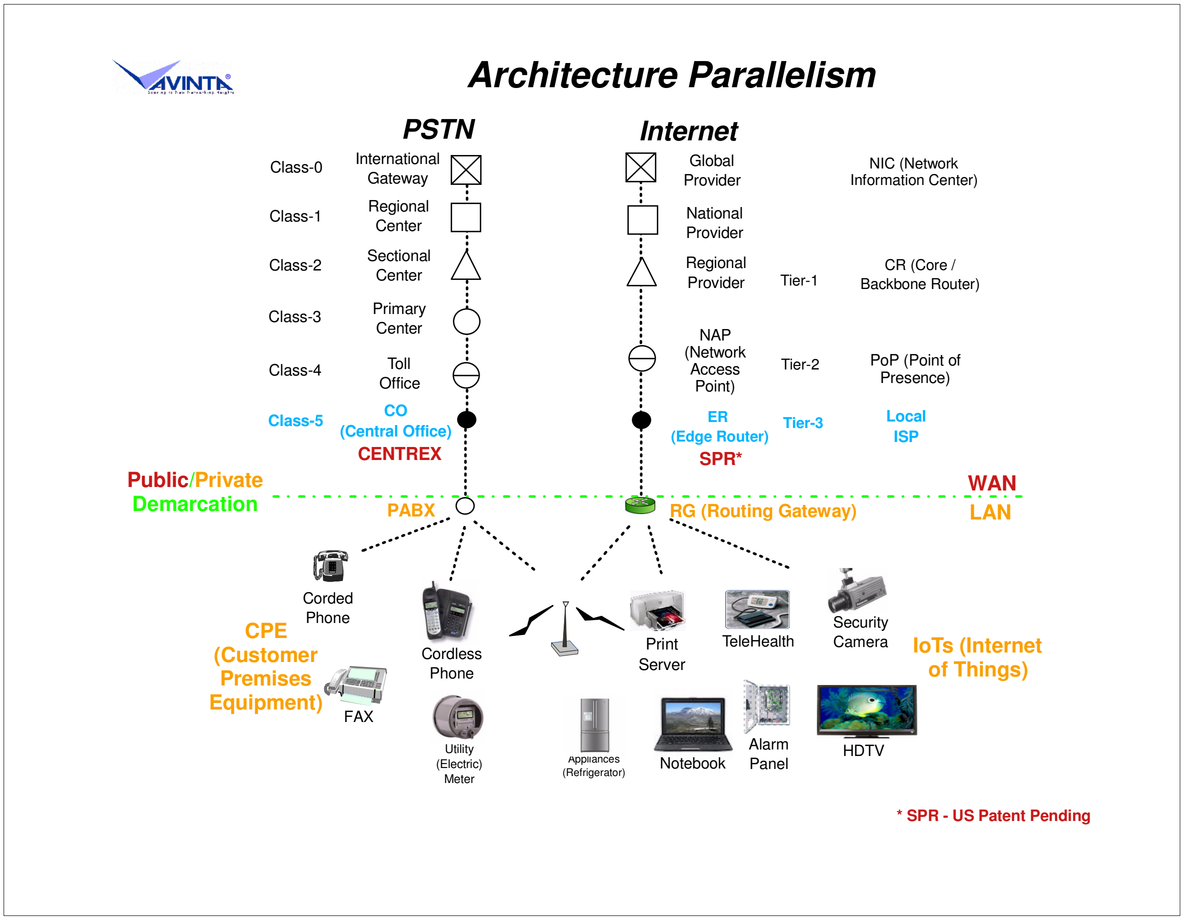
- After using one ER to host the entire current Internet, the remaining 239 ERs are ready to support additional similar-sized networks. This proposed architecture essentially transcends the current Internet fabric (CR & ERs) to become the backbone of a Super-Internet consisting of multiple worldwide communication systems.

F. Summary

- **Address Expansion**
  Multiply each IPv4 address by 256M fold
- **Deployment Configuration**
  Autonomous Sub-Internets
- **Operation Discipline**
  Inherent GeoLocation Property
- **Enhanced Architecture**
  CR with ERs as Super-Internet Backbone
- **Growth Ready**
  239 new worldwide Internet-sized networks

- **Address Expansion: Each IPv4 public address may now serve a stand-alone area with population up to 39M. Thus, most countries require only one public address to serve all needs.**
- **Deployment Configuration: Making use of the Caching Proxy technology as the gateway building block, each SPR service area becomes an autonomous sub-Internet, with most traffic confined within. Such traffic may be routed with 240/4 address in standard IP header, even without invoking the EzIP format.**
- **Operation Discipline: Instead of being ISP owned private properties, regard IP address as public resource. So that its administration can mimic the PSTN practices for telephone numbers, mitigating the root-cause of CyberSecurity vulnerability.**
- **Enhanced Architecture: The combination of the CR and 240 ERs may be viewed as the infrastructure fabric of a Super-Internet. Each ER manages one /8 block of 16M IPv4 addresses. Each such address terminates in an SPR with 256M addresses. The first ER will be used for the current Internet, with 80K times of spare capacity.**
- **Growth Ready: The remaining 239 ERs are ready to support new worldwide Internet-sized digital communication systems, normally working at arms-length from one another, yet fully interoperable through the same IPv4 protocol. The immediate candidate may be the satellite based Internet being discussed, or as testbeds for Internet architecture research.**



- This diagram demonstrates the architectural parallelism between the PSTN and the Internet by harmonizing their major functional subsystems.
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- Although basically defined as a hierarchical tree structure, telephone switching offices are often interconnected with direct trunks anywhere the traffic justifies. On the Internet side, the Tier-1 networks are fully mesh connected (peering), while Tier-3 networks are not. Tier-2 networks, providing connections between Tier-1 and Tier-3, may set up peering among themselves.
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- For the EzIP project, these details are insignificant, as long as the end points, either COs serving subscribers or ERs serving DSLAM (Digital Subscriber Line Access Multiplexer), CMTS (Cable Modem Termination System), or the equivalent, are able to communicate.
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- The SPR collocated with the ER is very much the same as the CENTREX being part of a CO. On the private premises, the RG is equivalent to a PABX.
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- The traditional telephony CPE is very much equivalent to the IoT. Although each may communicate through different technologies, many do have both interfaces. For example, telephone sets were traditionally served by analog signals from the PSTN. The VoIP technology provides the equivalent through the Internet. With the DSL from the PSTN also capable of VoIP, the division between the PSTN and the Internet is more blurred than distinct.