On the Study of Internet Ossification and Solution

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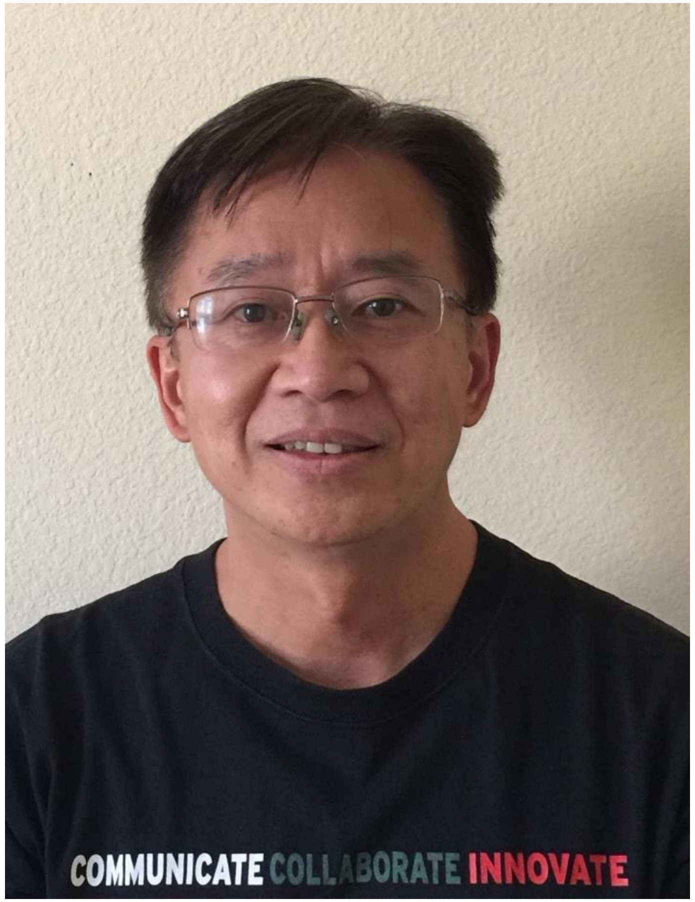
Bio

- Professional Experience
    - Distinguished Engineer, Futurewei Technologies, U.S.A (2019-Present)
    - Principal Engineer, Huawei U.S.A (2011-2019)
    - Technical Leader, Cisco Systems, U.S.A (1999-2011)
    - Software Engineer, Newbridge Network, Canada (1996-1999)
    - Engineer, Electronics Research Institute, Southeast Univ., China (1988-1994)
- Research Interest
    - Explore new network technologies for future Internet, including architecture, protocol, 5G and beyond, NTN integration, satellite networking.
- Activities
    - Work for “Focus Group on Technologies for Network 2030” in ITU, 2019
    - Rapporteur of ETSI NGP “Network Layer Multi-Path” WI, 2018
    - Rapporteur of ETSI NGP “New Transport Technology” WI, 2017
    - Papers for IEEE conference and More than 20 USA Patents
- Education
    - Master in Science, EECE, University of Toronto, Canada (1996)
    - Master in Electronics, EE, Southeast University, China (1988)



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Agenda

- Current Internet Architecture and Key Blocks
- Internet Ossification
- Root Causes of Internet Ossification
- Existing Research
- Vision for a Future Internet and Design Principals
- Scope of Future Internet
- New Network Protocol
- New Architecture
- New Control Plane and Data Plane

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Current Internet Architecture and Key Blocks

- Global system of interconnected computer networks that uses the Internet protocol suite to communicate between networks and devices (https://en.wikipedia.org/wiki/Internet)
  - Much bigger than the original definition
  - Networks: IP, Ethernet, MPLS, Optic, wireless access, broadband access, etc.
  - Devices: computers, phones, mobile devices, IOT devices, etc.
- Architecture:
  - Resource allocation and management (address, ASN): IANA -> RIR -> NIR -> LIR -> ISP -> EU
  - DNS service (domain name, domain name servers): root zone and root servers
- Protocols:
  - Layer 2 protocols (IEEE802.3, etc.)
  - Host configuration related protocols (ND[13], DHCPv6[14], etc.)
  - L3 or routing protocols (BGP, IS-IS [15], OSPF [16], etc.),
  - Traffic Engineering (MPLS [17], RSVP-TE [18], SRv6 [19], etc.)
  - L4 or transport protocols (TCP [20], UDP [21], etc.),
  - Upper layer protocols (QUIC [22], TLS [23], HTTP [24], etc.),

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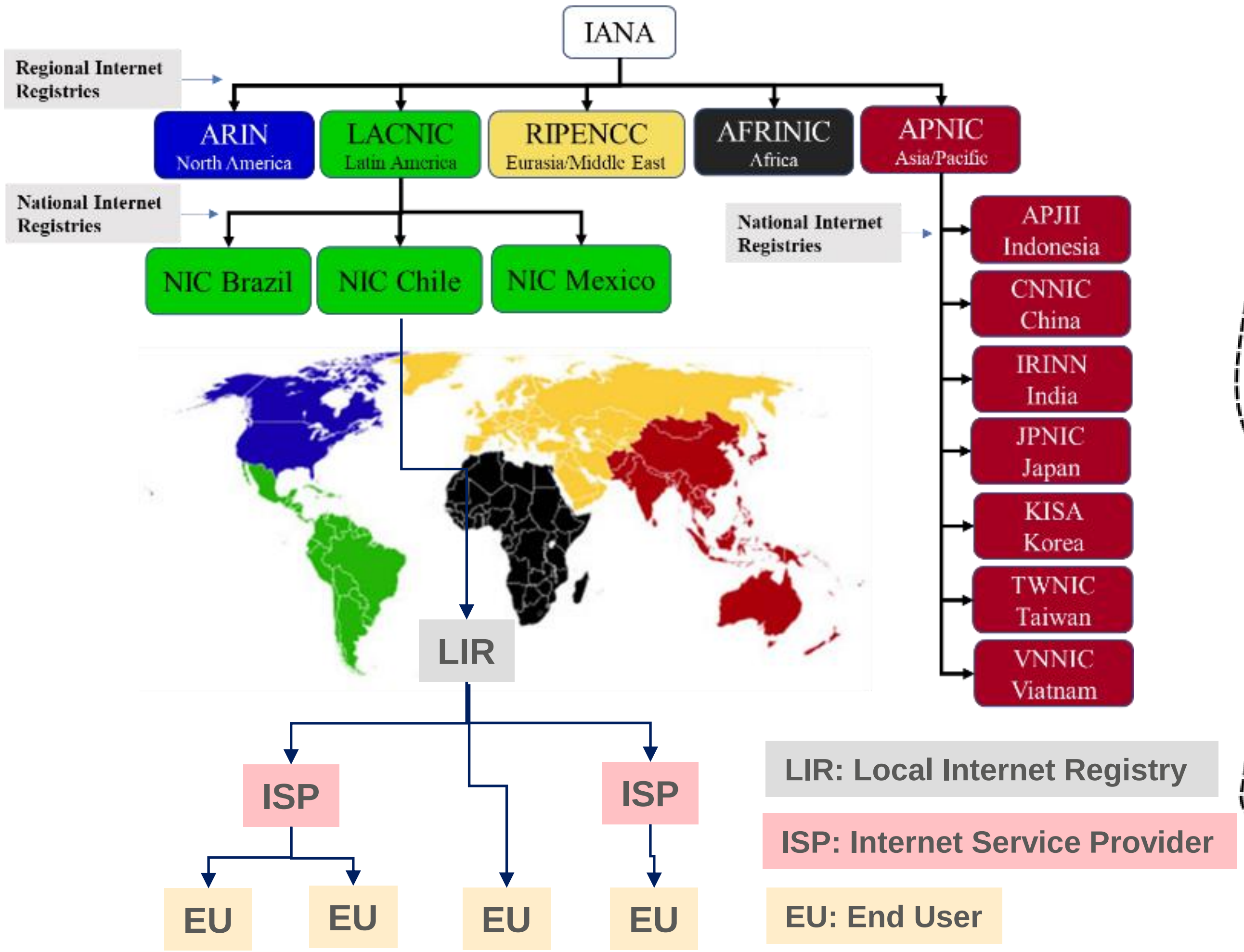
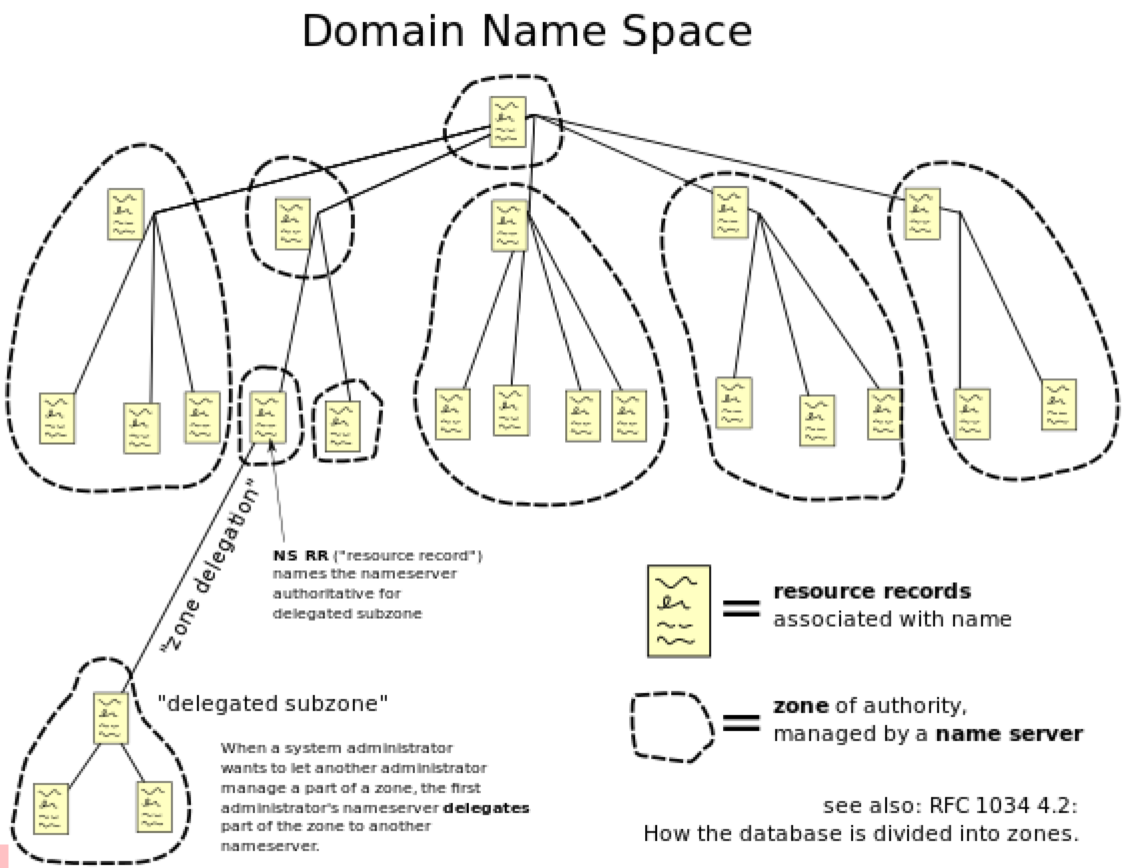
Architecture – Resource Management, DNS





https://en.wikipedia.org/wiki/Domain_name

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Internet Ossification

- Symptoms
  - Internet is far from perfect but almost impossible to change the infrastructure, from https://datatracker.ietf.org/meeting/112/materials/slides-112-coinrg-extensible-internet-00.pdf:
    - The public Internet seems doomed to architectural stagnation;
    - Internet increasingly balkanized
      - Private nets define own in network services
      - Public Internet lagging behind
  - Slow to add new features and change protocols
    - L4S (RFC9330, 9331, 9332): 2015 – 1/2023,
    - Very small changes to any protocol may need couple of years
  - Slow evolution
    - IPv6: 1st RFC2460 in 1998, IPv4 to IPv6 transition has not finished after more than 20 years
  - As comparison:
    - 3GPP: Finished spec of 5G in 2015, started 5G and 6G study, 10 year/generation
- Factors:
  - Non-technical
  - Technical

Root Causes of Internet Ossification

- Consensus challenges
  - Internet is a huge global network
  - Many technical definitions, solutions, and changes are globally significant
  - Consensus in wide range of stakeholders, including governments, organizations, operators, and individual users.
  - Different parties may have conflicting priority and interest. “Wooden bucket theory” takes effect.
  - Non-business driven (IETF: volunteer member vs. 3GPP: business member)
- Technical problems
  - Accumulated many technical feedbacks and problem reports.
  - Completely fixing those problems or enhancing the existing solutions are always slow
  - People are hesitating to accept drastic changes/fixing
  - Backward compatibility requirements

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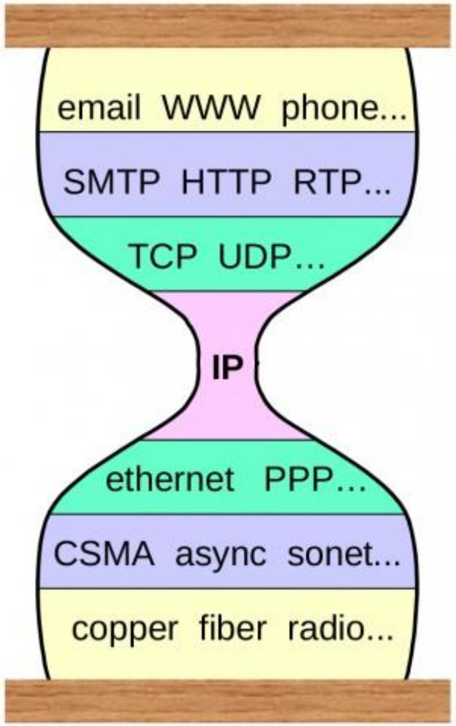
Design Aspects

- TCP/IP was Initially designed for computer network
- Narrow Waist of IP for Internet
  - Status
    - IP address is global significant
    - Flat Network
  - Pros:
    - Simplicity and Scalability
  - Cons:
    - Rigid IP header
    - Hard to change any bit in IP
- IANA based centralized architecture
  - Resource allocation fairness?
  - Jurisdiction for digit asset, regulation, laws?
  - Resilience to geographic interruption?



Steve Deering, "Watching the Waist of the Protocol Hourglass", IETF 51

Existing Research

- RINA: Recursive Internetwork Architecture
  - Clean-slate Internet architecture. Solve the Transmission complexity and performance issues caused by separation of TCP and IP, and TCP overhead; Multi-homing and mobility issues caused by IP address and port number at the same low level; Management and security vulnerability caused by IP address.
- SCION: Scalability, Control, and Isolation on Next-generation Networks
  - Clean-slate Internet architecture designed to provide route control, failure isolation, and explicit trust information for end-to-end communication.
- New IP
  - Based on IP. Evolve, upgrade, improve the Internet to implement and support future and emerging applications, in particular, applications enabled by 5G/B5G/6G.
- IPv10
  - Communication between IPv4 and IPv6
- EI: Extensible Internet
  - Based on IP. Add new server layer 3.5 (SL) to provide new service to hosts. New service include Basic, Other delivery model, Security/Privacy, Other framework, Other architecture. All changes are software based and within the private network or after the last mile of public Internet

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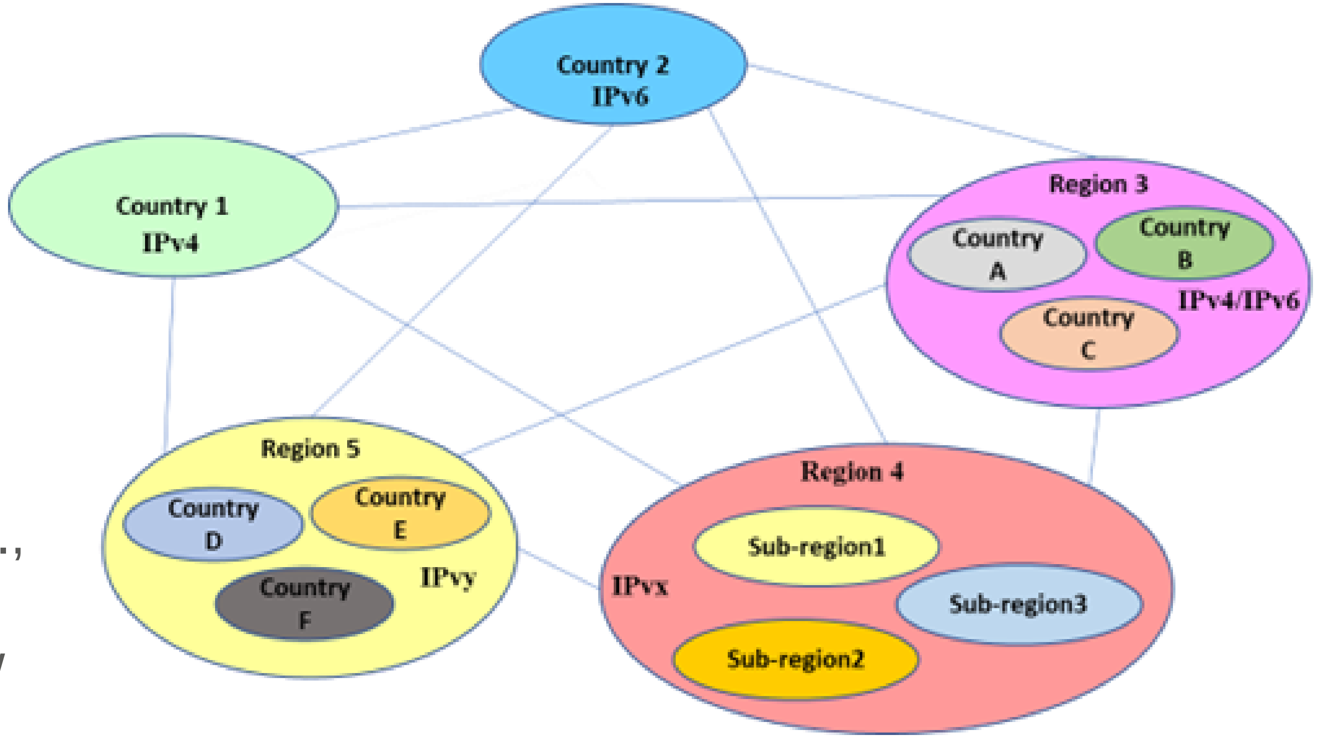
Vision for a Future Internet and Design Principals

- What other global communication do
  - Mail system
    - Only agree on the country name;
    - Only use the destination country name to deliver the international mail.
    - No restriction for local address format in a country, and the local mail delivery infra
  - Phone system (wired or wireless)
    - Only agree on the country code;
    - Only use the destination country code to make international call.
    - No restriction for the local phone number format in a country, and the local phone network infra.

- What Internet should be
  - Have more Democratics and freedom, less restrictions and centralization.
  - Should be distributed globally based on region or country. All regions are equal and there is no central control. No region can impact other's decision in address selection, peering and service.
  - Small countries can decide to form a region if the countries do not want to be independent in internet resource and DNS management due to economy and other constraints.
  - Each region has the freedom and authorization to manage the internet resource (Address selection, Address allocation, Asynchronous System Number allocation, Domain name registration, DNS root server).
  - Support heterogeneous communications.

Scope of Future Internet

- Only for the Interconnection between regions and countries
- No control for internal communication within region
- IP or other existing network in a region or country can still work
- Why:
  - Most of service are from local, e.g., Edge computing, Edge cloud, etc.
  - More and more regulation and law require data protection and localization



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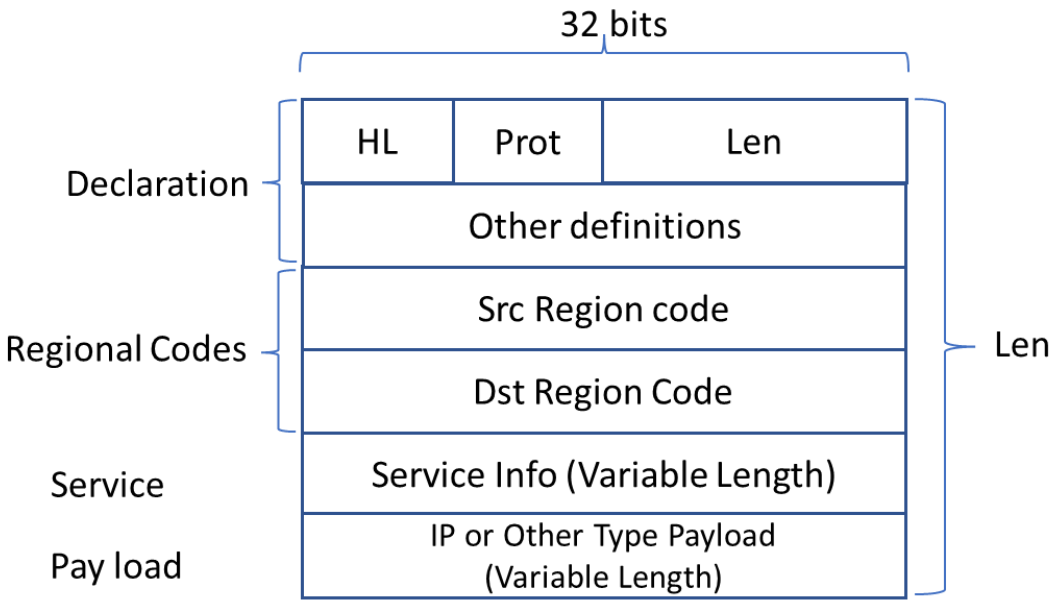
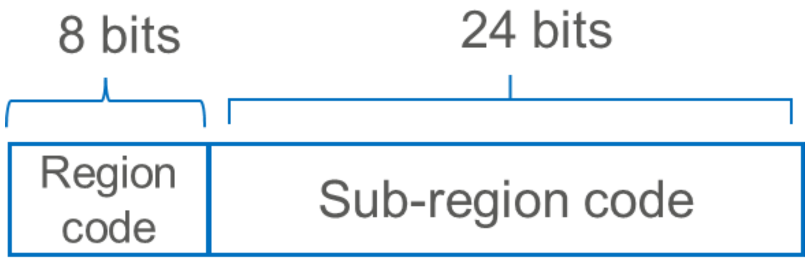
New Network Protocol

- Region code is key, fixed for each region and country, assigned by international organization; 16-bit or 32-bit are enough
- Payload can be any from L2 to L4





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New architecture - Internet resource management

International organization managed items:

1. The Region code structure and Region code assignment are responsible by international organization, ITU or IANA.
2. The global address format: e.g., region code: local address
3. For the protocols that the interconnection between different region or country are supported, i.e., The new protocol defined by this paper (new EtherType), IPv4, IPv6, Ethernet, MPLS, etc., the protocol numbers are still managed by international organization IANA.

Regional authority managed items:

1. The sub-region code assignment and management. The local address format
2. IPv4/IPv6 address and ASN number allocation and management for its own jurisdiction area. Different regions or countries may have different policies and schemes to manage the resource.
3. Each region or country can use the whole IPv4/IPv6 address and ASN space. All addresses only have local significance in the region or country, thus different regions or countries may have the same address.
4. Each region or country can define new protocol that are only used locally within the region. Or enhance the current IP and other network technology in the region without others agreement.

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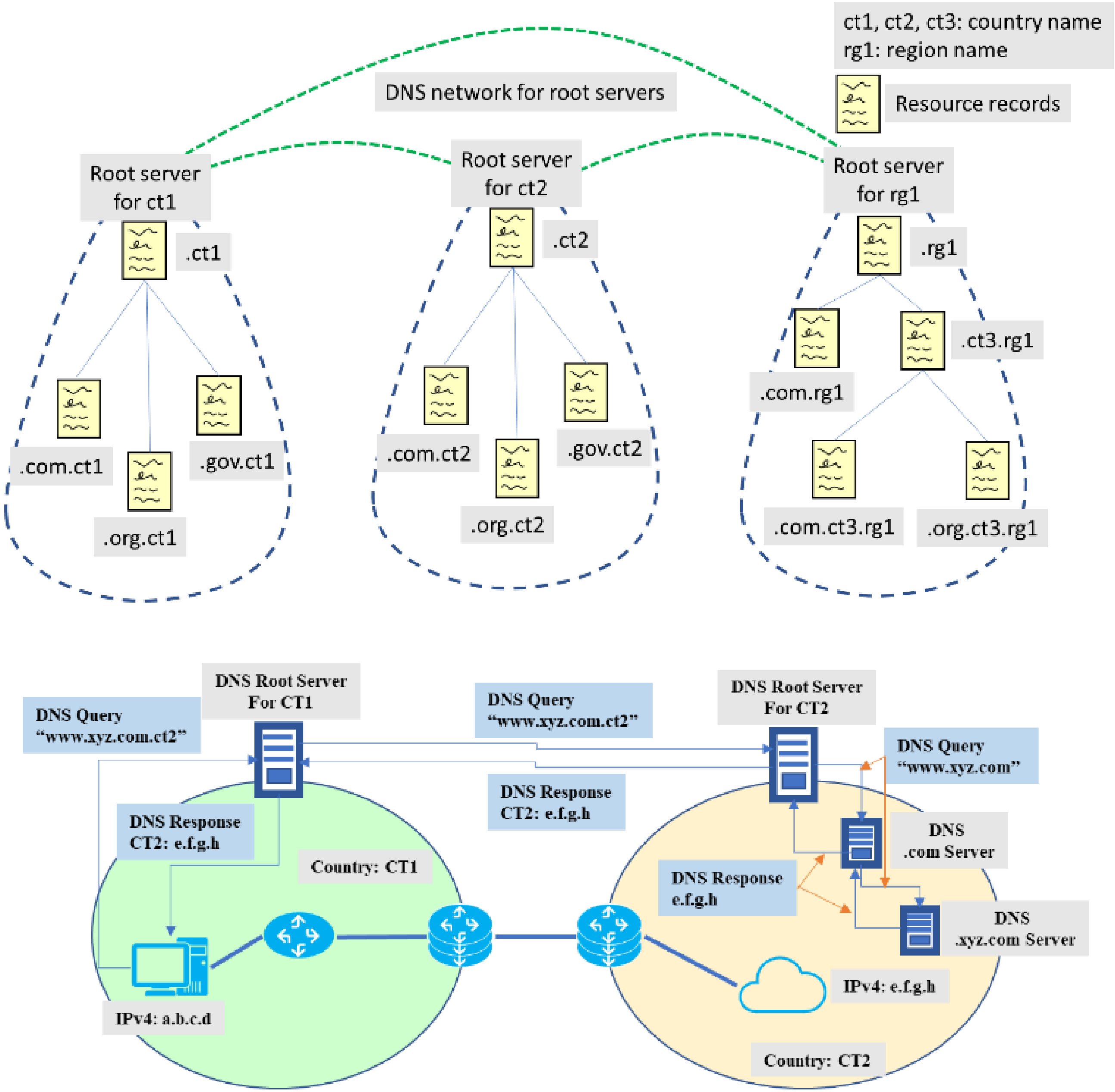
New architecture - DNS

- Each region/country has and manages its root server(s).
- All root servers of different region/country are equal and form a DNS network
- All root servers decide its own peering relationship and exchange the DNS information as agreement



New Control Plane

- The border devices connecting different regions need to support the new control protocol.
- The new control protocol will exchange information about the interconnected border devices, the associated links, the region code, and the reachable end-user's address details, etc.
- The new control protocol could be link-state routing protocol like IGP, or path-vector protocol like BGP.
- The new control protocol also must be running within a region or a country to populate the information learnt from border devices about the outside interconnected networks of other regions or countries.

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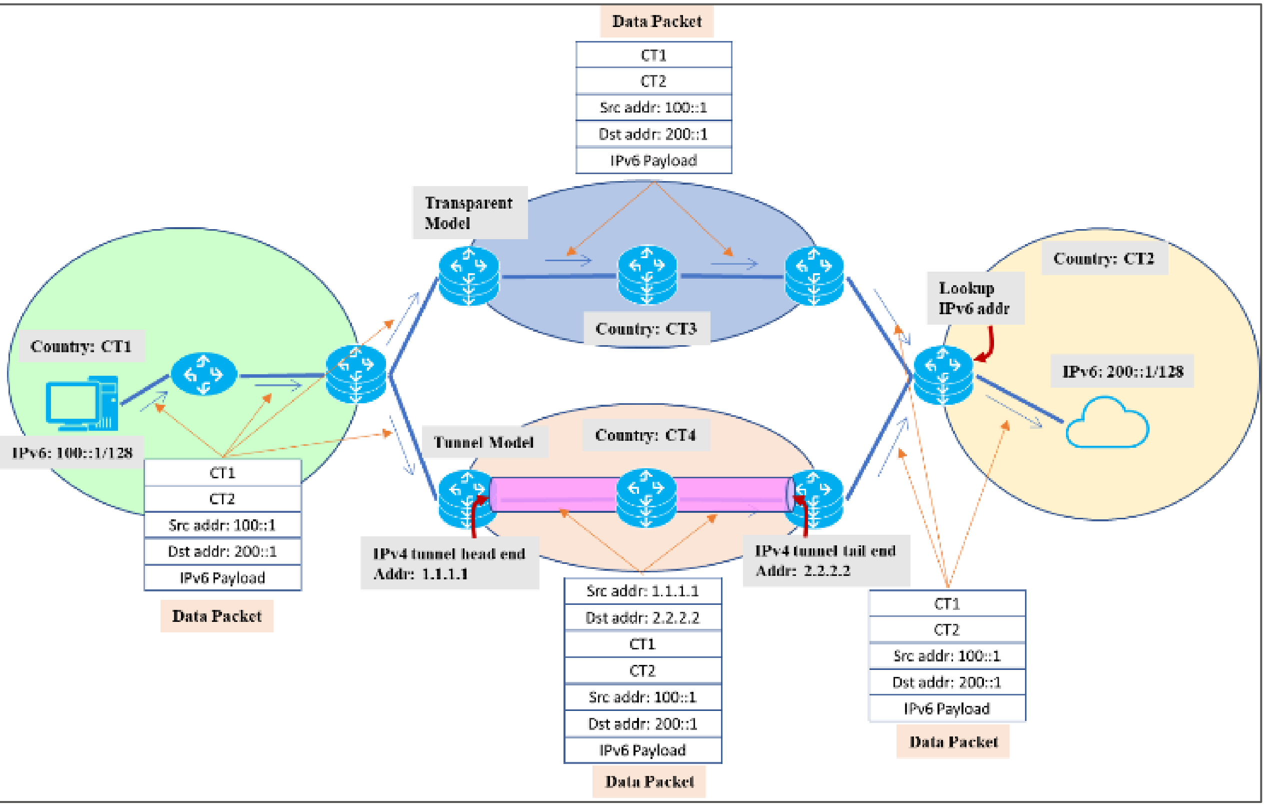
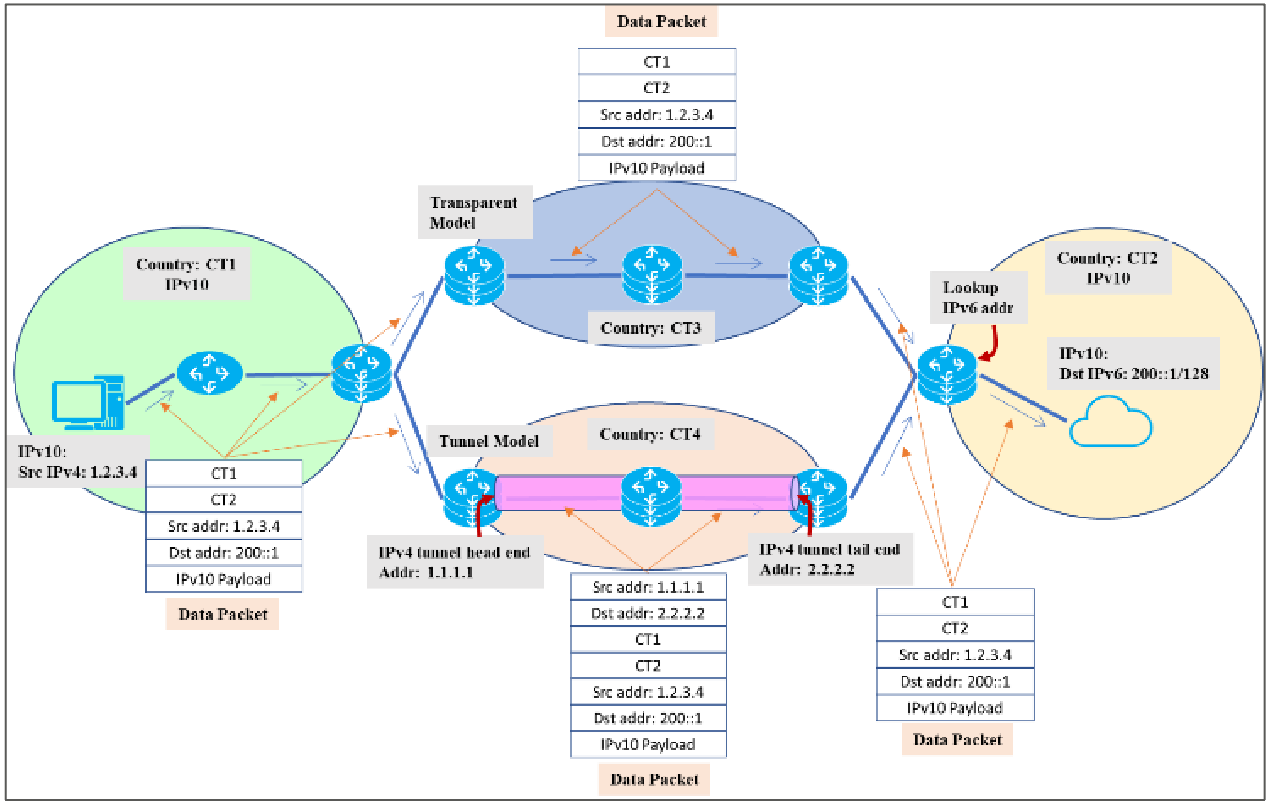
New Data Plane



Homogeneous Communication



Heterogeneous Communication

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Conclusion

- Benefits:
  - Much less restriction for the protocol for network interconnection
    - Only regional interconnection is changed, no change for the communication within the region
    - Relax the restriction for the network in a region.
  - Minimized changes on the current Internet architecture
    - IP can still used for the communication within the region
  - Independent technology evolution
    - Relax the need of global consensus for Internet innovation. Technology can evolve in a region and has no impact to whole Internet
  - Distributed Internet resource management and DNS
    - Real distributed architecture, more space for internet resource,
    - Localization requirements from regulation/law will be satisfied by the architecture.
    - More resilience and robustness for Internet.
- Advantages to existing proposals
  - Not clean slate solution, unlike RINA, SCION
  - Orthogonal to other solutions: IPv10, New IP, EI

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