IETF – RTG WG Interim

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What is Semantic Routing? & What problems is it solving?

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What is driving this?

- Some advanced applications are very futuristic and some are “imminent”
  - Holographic conferencing
  - The Metaverse
  - LAN gaming centres with more than 2000 seats
  - Collaborative video streaming
  - VR and AR equipment is affordable for the home market
  - Telesurgery
- Nearly everything has moved to some form of Cloud infrastructure
  - Rapid advances in connectivity technology enable new thinking
- Numerous high-capacity last mile options available
  - Fibre to the premises is a reality even in backwards countries like the UK
  - 5G offers significant bandwidth improvements
  - LEO deployments are literally taking off
- Wi-Fi-enabled public infrastructure for service applications and industry IoT devices are commonplace
  - Backhauling of application and sensor data across the Internet to Cloud platforms

5G Health Use Case (just one example)

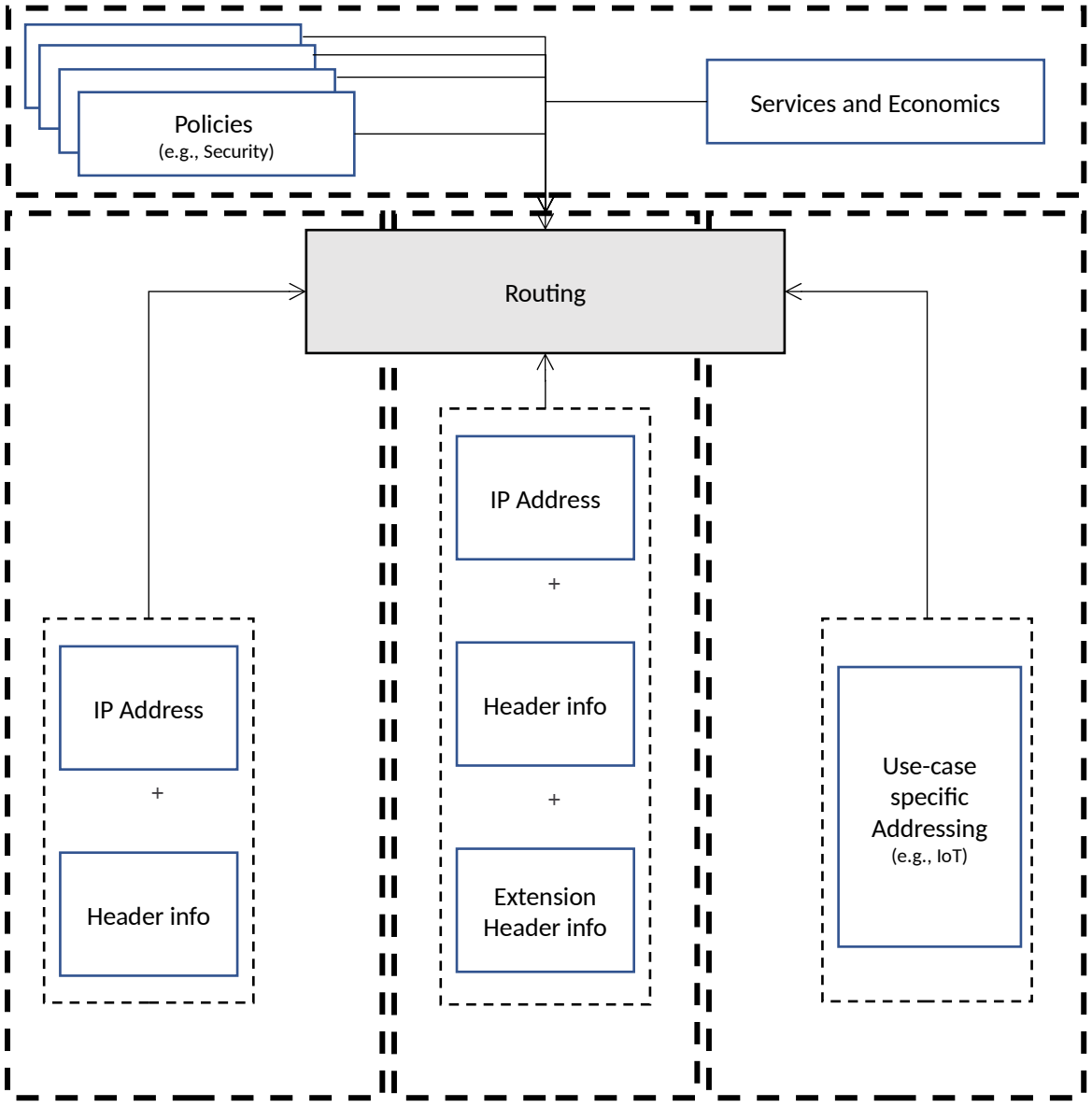
- Internet of Medical Things (IoMT)
  - Increasingly smart medical devices will be Internet-connected and store data in Cloud platforms
  - Connected Medical Devices
    - Real-Time Patient Monitoring
    - Personalized Remote Care
    - Active and reactive safety devices
  - IoMT devices and applications require better control of traffic
    - Traffic steering
      - Better/different security; privacy; supporting different topologies; mobility; Limited domains (LDs)
    - Preferred Path Awareness
      - “Preferential Routing”, “Policy-based Routing”, “Flow steering”
    - Better QoS

Advanced applications, what is the impact on routing and forwarding?

- A need for enhanced service delivery
  - Low latency, high bandwidth, low loss, bounded jitter, resilient, and increasingly energy-efficient
    - Latency is largely a function of distance
    - This means that many applications will still need to be smart
  - Potentially very many different grades of service for different applications
  - Can flows be routed onto different paths to meet SLAs/SLOs?
    - And if so, how are the packets marked for appropriate routing?
  - Is this just “QoS on steroids” or is it more sophisticated?
- Can we just throw more bandwidth at the problems?
  - Bandwidth can solve a lot of problems, but it is still finite
- Should an address continue to identify just an end point?
  - Or should we address services that may be realised in different places?
  - Is an address just a short-lived session token (like in QUIC)?
  - Maybe “names” will replace addresses?
    - DNS is getting stretched way beyond its original design
    - But name resolution is much slower than service instantiation

Routing/forwarding operation is well known

- Internet routing is based on Internet addresses
  - Originally just about reachability (destination address)
  - Routing finds the least cost path to the destination
- Evolution applied more sophistication
  - IP header information supplies more context for forwarding
    - E.g., DiffServ
- Innovation uses header extensions for additional routing decisions
- Overlay and underlay techniques have been invented to provide additional context and control of forwarding decisions
  - Encapsulations and shims
    - E.g., SFC and MPLS
- Generally, all the above techniques are driven by user, application and operator policies and economics



What Is Semantic Routing?

- An umbrella term
  - Perhaps we should have called it “Semantic Networking”
- Packet-level, Layer 3, hop-by-hop routing and forwarding
  - Not overlays because that is not hop-by-hop
  - Not Traffic Engineering because that is less reactive/dynamic
- “Making routing and forwarding decisions based on semantic information carried in packets”
- In Semantic Routing additional information is placed in the packet
  - Describes the treatment the packet should receive and the functions to apply
  - Forwarding acts on the instructions from routing and the information in the packet
- Semantic Routing is composed of three elements
  - Routing
    - Determines next hops for each packet given network state and capabilities
  - Packet marking
    - Additional information is placed in the packet
  - Forwarding
    - Acts on the instructions from routing and the information in the packet

The Routing part of Semantic Routing

- Historically network-wide routing algorithms have been used to generate forwarding instructions in each node
  - Distributed, but identical algorithms (e.g., SPF)
  - Centralised planning algorithms
  - Based on information known about or gathered from the network
- The advanced applications suggest
  - Need to know more information about the nodes and links
  - Handle dynamic network state
    - Changes in queues, bandwidth, transmission quality, etc.
  - Advanced algorithms that produce different next hops for different purposes
    - Allows a packet to be sent on the best path according to the services it needs

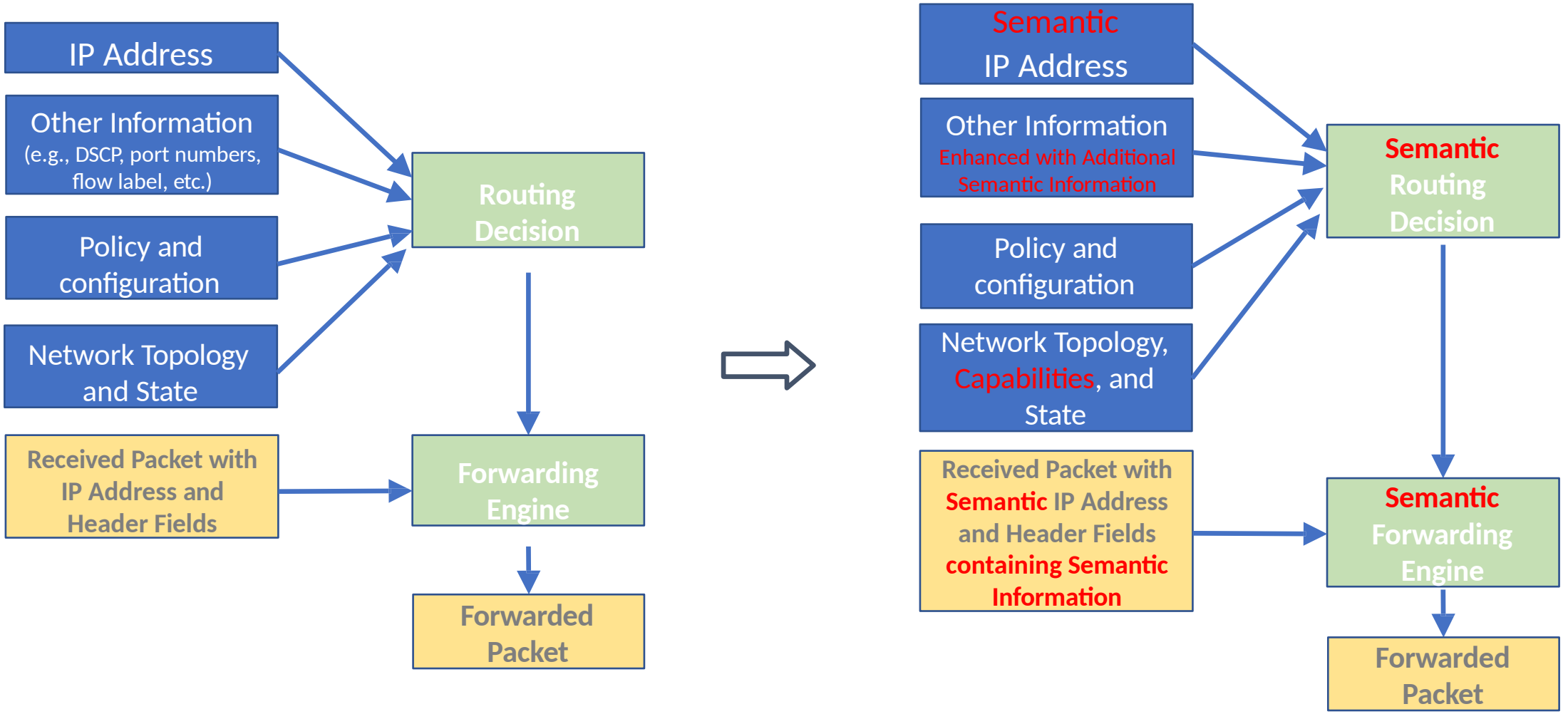
The Forwarding part of Semantic Routing

- Forwarding is instructed by routing
  - May be centralised or distributed
    - SDN with a controller
    - Classic IGPs
  - May use a network programming interface
    - E.g., P4
- Forwarding is a look-up keyed on semantic information in the packet
  - May be a simple table look-up
  - May also use local state information
  - May have a simple or sophisticated local algorithm
  - Or the semantic information may be the next hop instruction

The Packet Marking part of Semantic Routing

- Mark the packets so that forwarders know how to handle them
  - Use existing packet fields
    - Use existing flow identification fields (five-tuple, ToS, TC, Flow Label, payload, etc.)
    - “Overload” existing fields giving them new meanings
    - Repurpose part of an IPv6 address
  - Information may be carried in new fields
    - IPv6 Extension Headers
    - New “Layer 3.5” encapsulation
    - New MPLS Special Purpose Labels with ancillary data

Architecturally, its not a big deal



- But this is an overly-simplistic functional representation
  - What are the architectural implications of adding more information and more decisions?
  - And what are the consequences for the existing routing system?

Why talk about this?

- “All routing and forwarding is Semantic Routing and Semantic Forwarding”
  - Furthermore, many existing schemes already apply some element of Semantic Routing
  - Yes, and we’re looking at how this is extended and what the implications are
- A survey of old and more recent work (draft-king-irtf-semantic-routing-survey)
  - Research and engineering proposals
  - A very long and incomplete list
    - In many cases the purpose is to achieve different forwarding behaviours based on advanced routing algorithms
    - In a lot of cases the intention is to apply the mechanism within a “limited domain” [RFC8799]
    - Very many different motivations and use cases
- Need evolution not revolution
  - Hence discussions about:
    - What we are trying to achieve
    - What the concerns and risks are
    - What the architectural options are
    - Some strawmen for possible technical solutions
- Read more in draft-farrel-introduction-to-semantic-routing