UCL DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING
INFORMATION AND COMMUNICATION ENGINEERING GROUP

Towards Service- and Application-Aware Ultra Fast Networking

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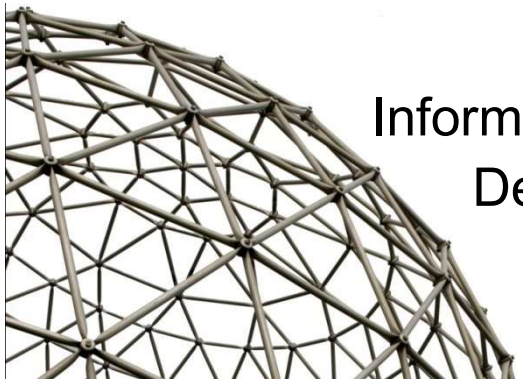

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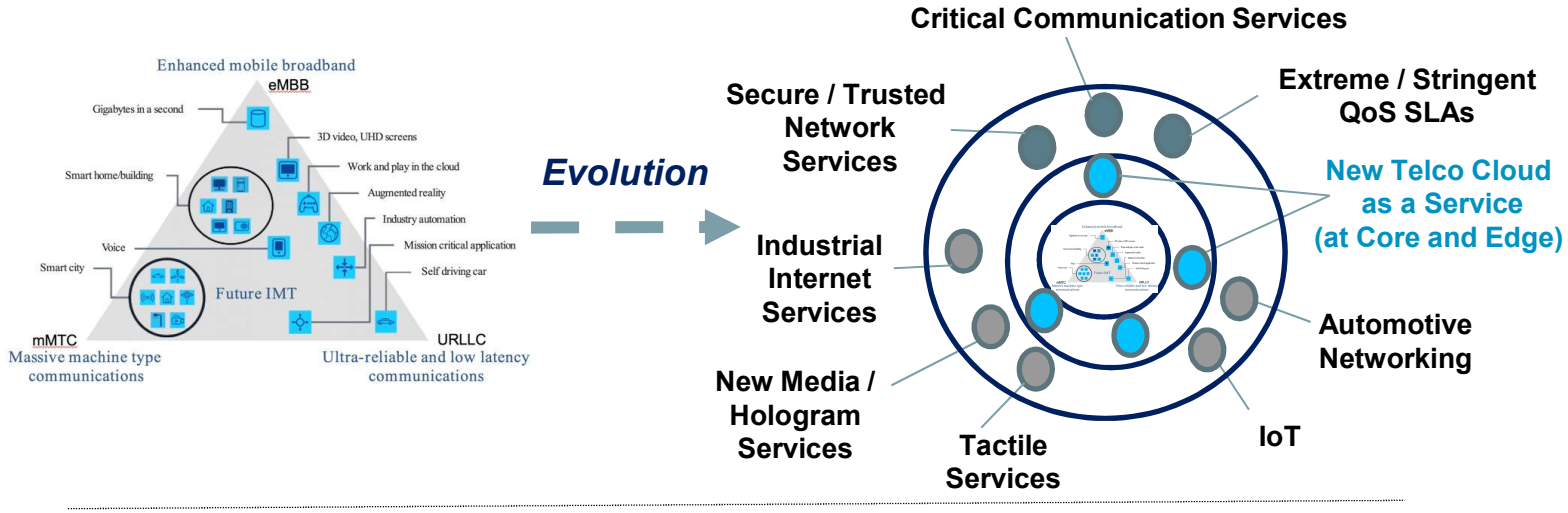
Network Services Evolution



Present Digital Network Services & 2020 Network Services

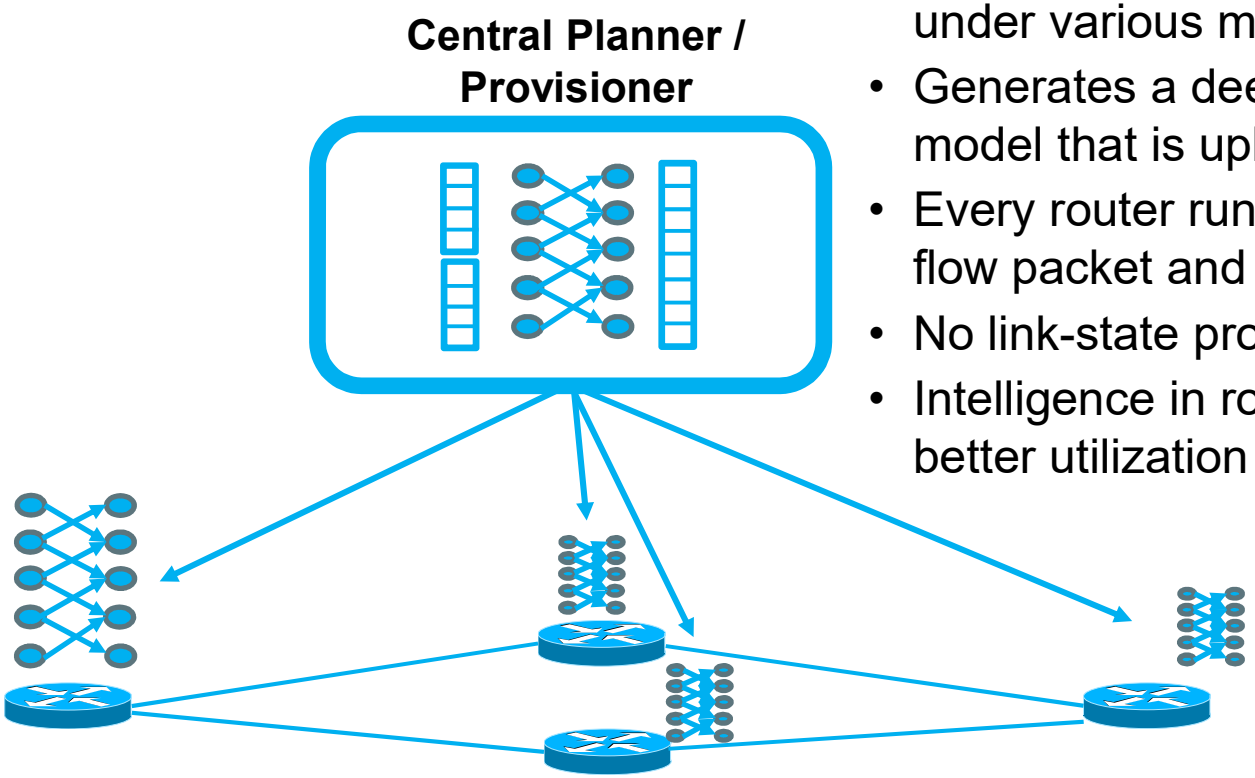
2030 and Beyond Network Services

- Evolution of network services towards: very low latency, very high bandwidth, very high reliability / resilience, trustworthiness and privacy
- In-network computation a key aspect, evolution of telecom clouds to support computation for third parties in both the core and edge
- Network programmability a key architectural principle / design choice to enable soft network evolution as requirements change

Research Areas Addressed at UCL EEE

- A number of research areas that contribute collectively in this direction are addressed at UCL Dept. of Electronic & Electrical Engineering
  - Neural routing and network-based congestion control (zero queuing) through deep reinforcement learning
  - Intent-based networking for declarative closed-loop network configuration, supported by adaptive line-speed traffic monitoring
  - Service routing without DNS-based resolution, with service addresses encoded in IPv6 packet headers – backwards compatible approach
  - New IP framework and protocol with meta-information in the header to trigger appropriate processing in routers for high-precision services
  - Big packet protocol as part of the new IP framework, with prioritized payload dropping for continuous media flow under adverse conditions

Neural Routing

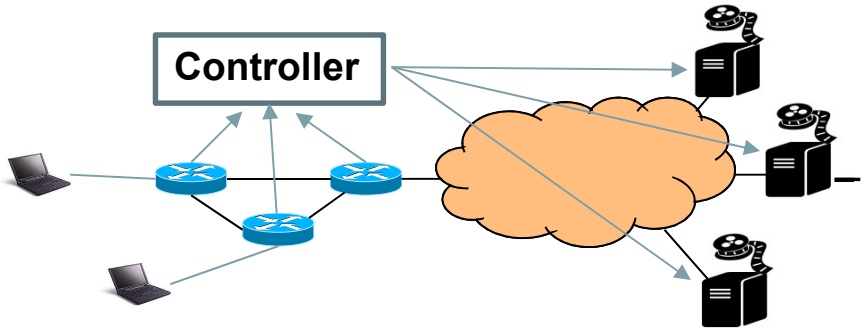


- Central Planner simulates the network under various measured traffic conditions
- Generates a deep reinforcement learning model that is uploaded to the routers
- Every router runs the model for the first flow packet and creates forwarding state
- No link-state protocol / MPLS in routers
- Intelligence in routing decisions, resilience, better utilization / load-balancing

Network-based Congestion Control

Motivation:

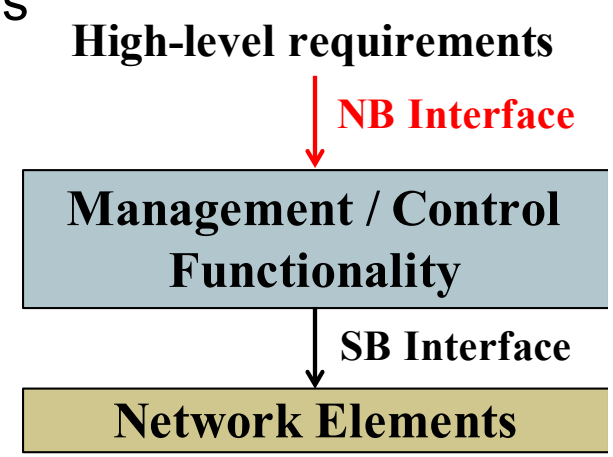
- "Zero queuing"
- Different utility functions
- Plug-in fairness



- Applied to eye-ball / edge domains
  - Elephant flow traffic is reported / monitored
  - Controller uses machine learning to produce optimal sending rates for each sender
  - Reinforcement learning algorithms based on Asynchronous Actor-Critic Agents (A3C)
  - Enforces the rates either by modifying TCP window size on the fly or through a control channel (requires transport modifications)
  - Encouraging first results

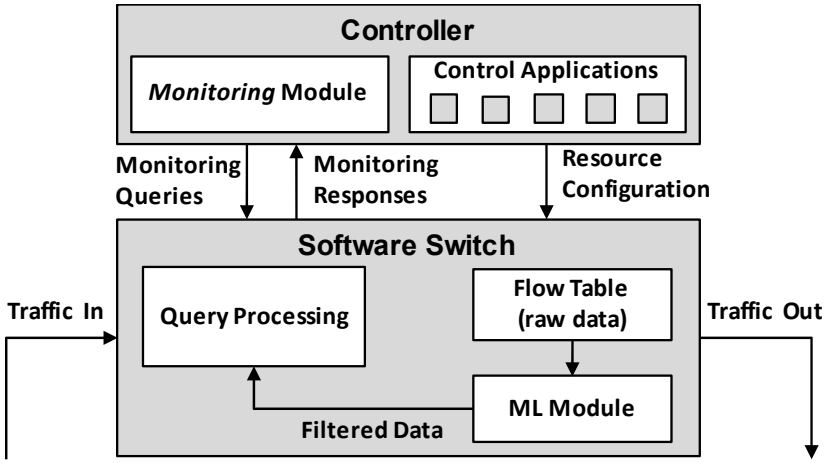
Intent-based Networking

- "Don't tell me what to do, tell me what you want"
  - Overcome configuration complexity using declarative directives
  - Decomposition of requirements to configuration commands
- Functionality realized through SDN North-Bound Interface
  - Automatically associates requirements to mgmt. functions, resources and commodities
  - Simplifies configuration process and avoids configuration inconsistencies
  - Allows frequent changes to high-level requirements
  - Facilitates faster service deployment
  - Smartness and adaptability in network operations and management
  - Key issues: conflict detection / resolution, coexistence with hard-coded applications



Adaptive Line-Speed Monitoring

- Management & control applications require timely and accurate monitoring data for closed-loop enforcement of intents
- Adaptive line-speed monitoring of software-based networks
  - Scalable (#devices, network diameter)
  - Programmable (measurement task, frequency, granularity)
  - Adaptive (new requirements, network dynamics)
- Efficient monitoring techniques at high packet rates
  - Process large amounts of state information in very tight timeframes
  - Reduce query processing time and memory consumption
  - Machine Learning (ML) to filter out unwanted data and classify flow entries according to monitoring task



Service Routing

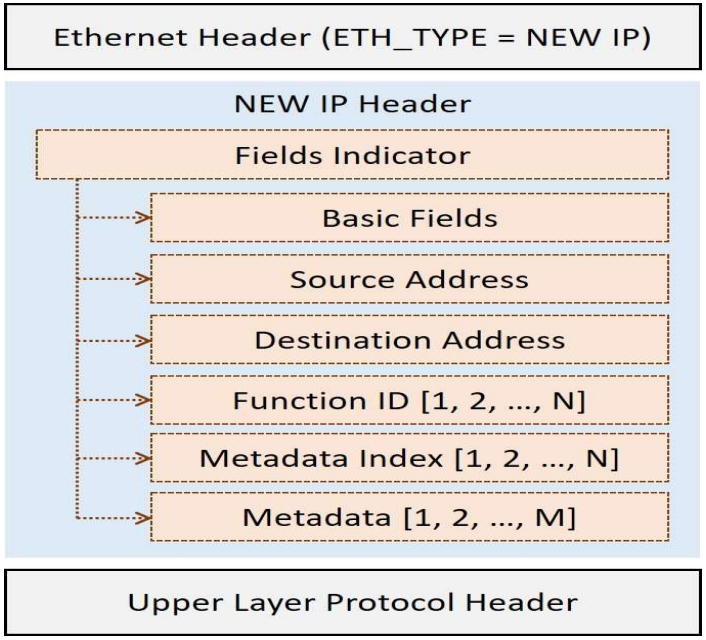
- DNS resolution overhead is unacceptable for latency-critical services, such as e.g. AR/VR, that require responses from service logic deployed close to the users
  - DNS resolution itself is much greater than the required service response time, which could be less than a few 10s of milliseconds
  - Also applicable to services/applications that use in-network computation in dynamic Edge/Fog Computing environments
- Service routing: route packets based on service names
  - No DNS resolution at all
  - The network performs *late-binding* of service names to locations
  - Key issue: find an incrementally deployable solution using current IP

Service Routing using IPv6

- Applications hash the first name part (e.g. www.AR.com) to obtain the IPv6 prefix and hash the suffix to obtain the serviceID
  - Service routers (SRs) map IPv6 prefix and serviceID to next hop – for legacy (i.e. non-service) routers, longest prefix match will still work
- Each service has service information maintained in SRs
  - Maximum capacity, current load
  - Ultimate goal is to route requests so as to jointly optimize network and service resources (latency, bandwidth, service capacity, load balance)
- Issues currently researched on:
  - Routing information scalability, forwarding strategies, service information metrics and other

New IP Framework for High Precision Services

- Key idea: include meta-information in variable length header to support programmability re how to process/forward packets in routers
  - ➢ Service-aware packet processing in routers considered together with network conditions could be used to support KPIs for future high precision services
  - ➢ Huawei/UCL short paper to appear in NOMS'2020*

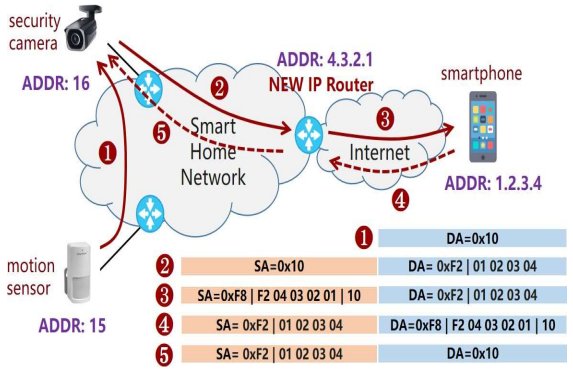


- **Variable IP address length** to seamlessly support communication across different network domains, e.g. fixed Internet and IoT
- **Semantic IP address definition** to identify both physical and virtual entities
- **User-extensible IP header** allowing services / applications to specify functions to be performed on packets in routers
- **Flexibility in programming IP's header**

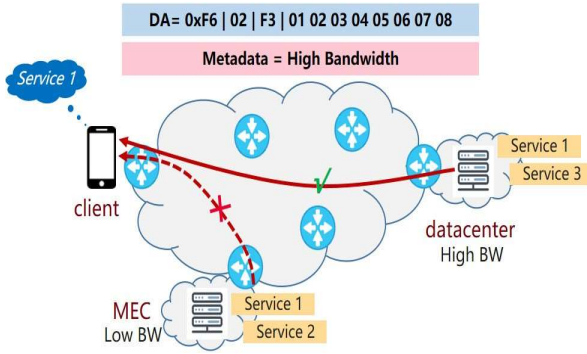
* Z. Chen, G. Li, Z. Lou, S. Jiang, A. Galis, "*New IP Framework and Protocol for Future Applications*", short paper to appear in IEEE/IFIP NOMS, 20-24 April 2020, https://noms2020.ieee-noms.org

Key Benefits vs Today's IP

- Service-aware packet processing based on network conditions for high precision services
- Service routing for faster service access without the DNS (see also slides 8/9)
- Dynamic provisioning of services and content given they can be accessed by name – service- / content-based routing
- Simpler implementation of network nodes in constrained environments due to variable length addresses



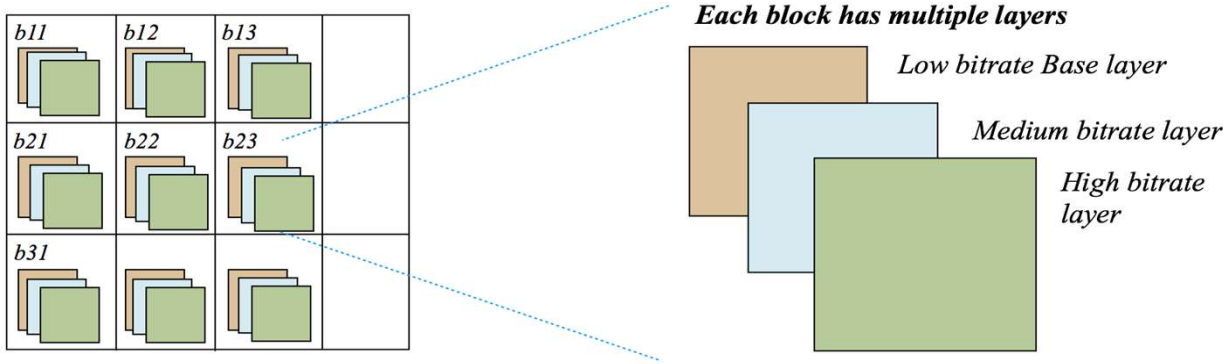
Home/Edge Automation



Routing Based on Service Needs

Media Big Packet Protocol (BPP)

- Specific part of the new IP framework, parts of media payload (“chunks”) are dropped in adverse conditions based on meta-data to avoid stalling
- Presented our work in Network 2030 in Geneva showing that BBP needs specific encoder/decoder and cannot use existing MPEG-DASH



- For future video services, BPP will need a scaling multi-layer encoder to embed multiple encodings of a frame into the same Macro Block
- We are currently looking at application-BPP interaction for VR/holographic services, putting different parts of the visible space into different chunks
  - Also at a feedback receiver->sender loop to take into account network state

Summary

- A number of areas addressed at UCL EEE that collectively contribute towards service-aware ultra fast future networks
  - AI-based Intelligent solutions to traditional problems, such as routing, congestion control and high-speed monitoring
  - Radical re-thinking of operations and management in a programmable manner through high-level intents
  - Service-based routing in a backwards compatible manner
  - Next-generation high-precision IP that supports programmability regarding the way in which service-aware packets are treated
- Network programmability a key issue and design choice for graceful future network evolution

More Information

- For more information on those areas you may contact the following people
  - Neural routing and network-based congestion control:
    Prof. Miguel Rio miguel.rio@ucl.ac.uk
  - Intent-based networking and adaptive line-speed monitoring:
    Prof. George Pavlou g.pavlou@ucl.ac.uk
  - Service-based Routing:
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  - High precision new IP:
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  - Big Packet Protocol for Media:
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