Using IP to Underpin 5G Networks

Making the Unreliable Reliable

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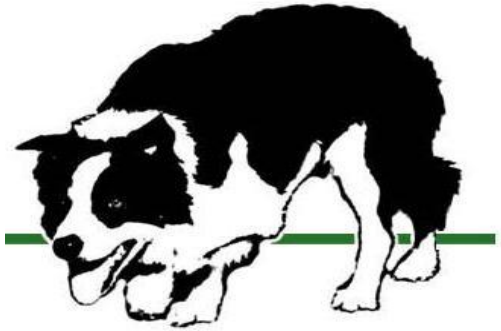

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Topics

- What Services do we Want to Enable?
- What do the Services Demand?
- What is an Underlay Network? Why use IP?
- But IP is “Best-Effort” isn’t it?
- How To Build Reliability over the Internet?
- Proposals to make IP Predictable
- Architectural and Deployment Considerations
- Evolution or Revolution?

5G and the New Services

- Lots of pizzazz and hype!
- But, this is not really about 5G, it's about new services on the Internet
  - 5G just makes them more broadly available
- New services will come along
  - Beware of using them as justification for technology
  - Look for the real services and applications
- What applications?
  - Remote surgery
  - Haptic interactions
  - Holographic conferencing
  - Multi-player VR or AR gaming
  - Vehicle automation
  - Manufacturing
  - Crowd-sourced video
  - Digital trading

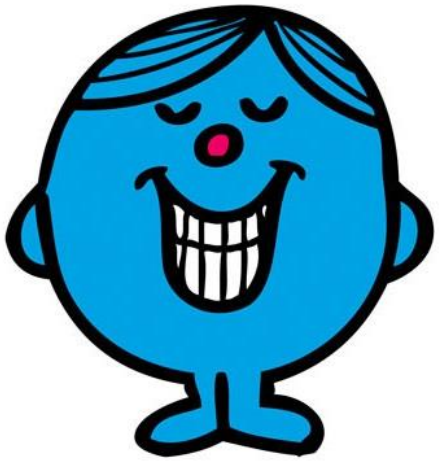
New Services Need New Network Behaviours

- Most of the new applications demand some improvement in networking
  - Greater bandwidth (throughput)
  - Lower delay (less latency)
  - Less variation in delivery time (reduced jitter)
  - More independence (less impacted by other traffic)
  - Better reliability (less packet loss / corruption)
  - Better resiliency (less affected by network failures)
- This is not a new list!

The Underlay Provides Connectivity

- Every connection has an underlay providing connectivity
  - Even the fibre is carried in a duct
- But “underlay” is subjective
- We care about connectivity provided for our application
- The applications we are talking about run over the Internet
  - That makes IP the prime candidate
- 5G applications and network segments can be connected
  - Probably over the Internet
  - Again, IP is the candidate “underlay” network

So Who is Perfect?



- IP was designed with specific design goals
  - It is a simple encapsulation for end-to-end delivery
- The IP network also had simple-to-state goals
  - Connectionless network (no state in the network)
  - Recovery from network faults
  - Best-effort delivery
- Everything else happens in other layers
  - Lower layers may be made reliable and may include traffic engineering
  - Higher layers may include retransmission, security, prioritisation
- Thus, IP is not:
  - Predictable
  - Dependable
  - High-quality

How To Deliver Reliability Over the Internet

- Many technologies exist to underpin the Internet
  - Ethernet, MPLS, OTN
- These do not provide end-to-end quality of service
- Solutions in hand look at how to provide predictability over IP
  - Real-time Transport Protocol (RTP)
    - As old as the hills (1986) and widely used (e.g. VoIP and WebRTC)
    - Helps handle jitter, packet loss, out-of-order delivery
  - Multi-Path TCP (MPTCP)
    - Experimental (2013) moved to standards track (2020)
    - Inverse multiplexing to maximise use of bandwidth and improve throughput
  - QUIC
    - Google proprietary (2012) brought to the IETF
    - Already widely deployed
    - Multiplexed connections and somewhat reduced latency
- In the dustbin of history?
  - Differentiated Services (DiffServ)
    - Somewhat used, but not substantially
    - Colour packets for different services
    - Allows prioritised queuing and different treatments at transit routers
  - Integrated Services (IntServ)
    - Fine-grain description of traffic flows
    - Prioritisation of traffic and reservation of network resources in conjunction with a protocol such as RSVP
    - Too complex and requires end-to-end support in the network

Making IP Predictable

- Increased pressure to make IP behave in known ways
  - Guarantee the quality of service
- Tends to drive some form of connection-oriented approach
  - RSVP placed state in the routers (not talking about MPLS)
  - Segment Routing places state in the packets and the management station
- Today's discussions are about:
  - Placing flow quality identifiers in the packets
  - Programming the network to handle packets differently
    - Different queuing and prioritisation
  - Assumes many things:
    - "Sufficient" network resources are available
    - Traffic never swamps the network
    - Central management can predict how to distribute traffic
    - Routers are aware of marking schemes to not congest traffic

Deployment Considerations

- What have we learned about deploying new stuff in the Internet?
  - Sub-IP
    - Can be done hop-by-hop but requires adjacent nodes to interoperate
    - Usually done in islands and can be slow to achieve
    - Incentive is operational or commercial
  - IP
    - Needs all routers in an administrative domain to be updated
    - Better if full end-to-end path is upgraded
    - Remarkably hard to show incentive (just look at IPv6)
    - May be practical in specialist networks
  - End-to-end (application level, or transport)
    - Just update the end points
    - Old versions continue to be supported (with lower functionality)
    - Easy to achieve
    - Incentive is either additional features or bundled in regular release packs

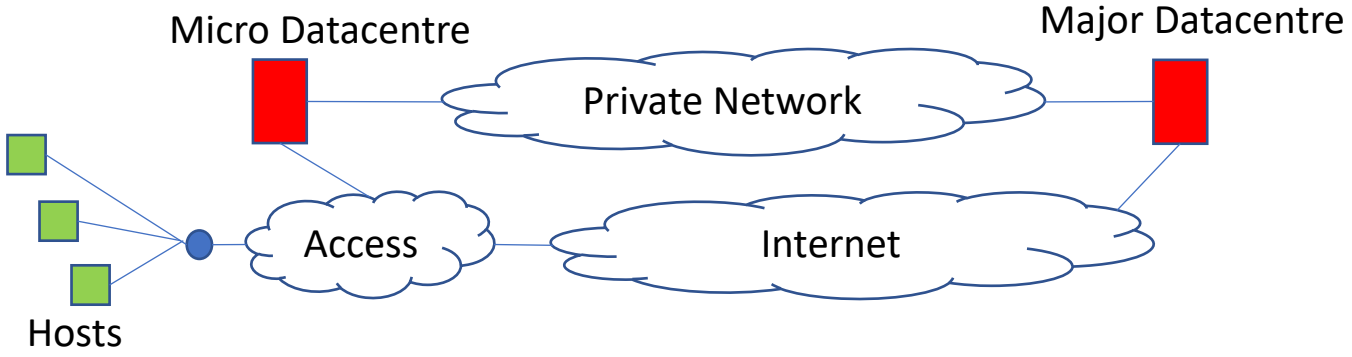
“Ye cannae change the laws of physics”

- But seriously, you can’t
- Yes, we’re squeezing a little more out of hollow fibres
- No, the speed of light is a limiting factor

- Thus, round-trip latency is governed by distance
  - People talk about <1ms round trip times for some applications
  - That’s 93 miles each way
  - Assuming no processing, routing, buffering
- That has many implications for how we architect our networks

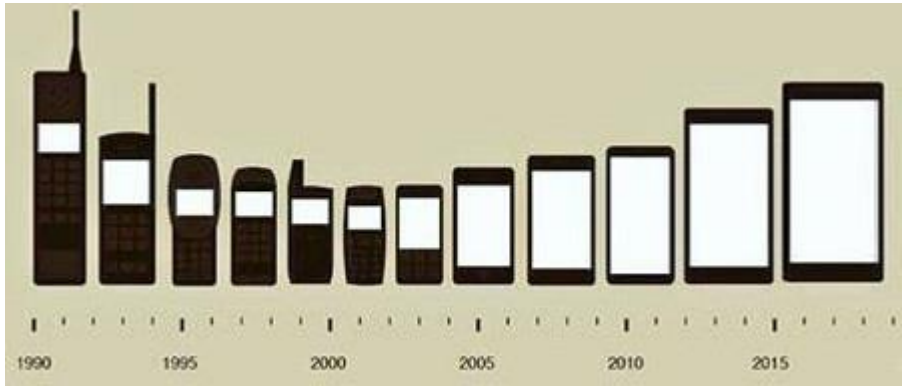
Network Architecture is Evolving

- Processing is moving to the edge
- Bandwidth is increasing
- Private connectivity networks link remote data centres
  - The Internet is, once again, a network of networks



- This doesn't help you if you want low latency across the world
  - Battlefield surgery conducted from the home nation
  - Multi-player inter-continental games
  - High-speed market trading
  - Sensitive haptic interactions

Evolution or Revolution?



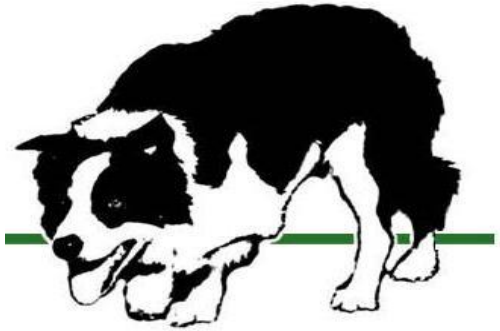
- Haven't we been here before?
  - Repeating cycle of concern
    - Internet will not scale
    - We need to do something
    - Bandwidth reservation
    - IntServ, etc.
  - But each time we have addressed concerns with increased capacity at a lower cost
  - Why do we think it is different this time?
- Do we try to "fix IP" or do we build a replacement?
  - Evolution or revolution?
  - Maybe neither, given what we know about deployment and architecture
- But what could we do instead?
  - Improve the underlay and the overlay
- We clearly need to spend time on research

Image after Loughlain McPherson

Research

- What applications and services do we ***really*** need to support?
  - There is a difference between dreams and immediacy
- What can we achieve by enhancing tunnelling and transport protocols?
  - What have we learnt from RTP, QUIC, and MPTPC?
- What could we do through better operations and management?
- How should we design our applications to handle network effects?
  - Don’t we already do this?
- What form does research take?
  - Experimental protocols and implementations
  - Quantitative measurements of network behaviour
- Where can we do our research?
  - Universities and corporate research labs
  - Publish in journals and at the IRTF

Questions and Follow-up



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