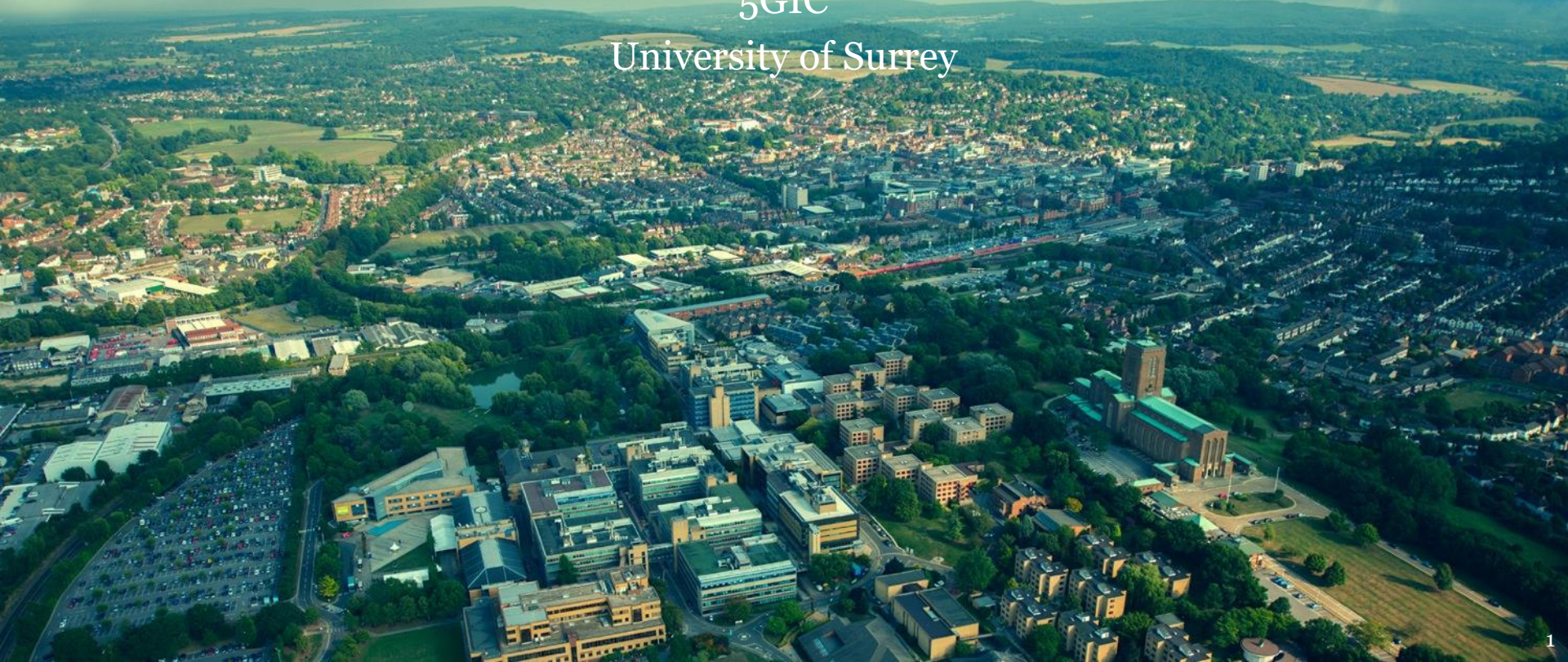# On the Driving Forces of Future Network Design - Capacity + Intelligence

Prof. Ning Wang, Regius Prof. Tafazolli

5GIC

University of Surrey

5G (and future networks) is...

CONNECTIVITY/CAPACITY + INTELLIGENCE

| Automation | Data to information/knowledge transformation | Blurring boundaries between real and cyber worlds |

Connected Devices of small and large sizes and capabilities
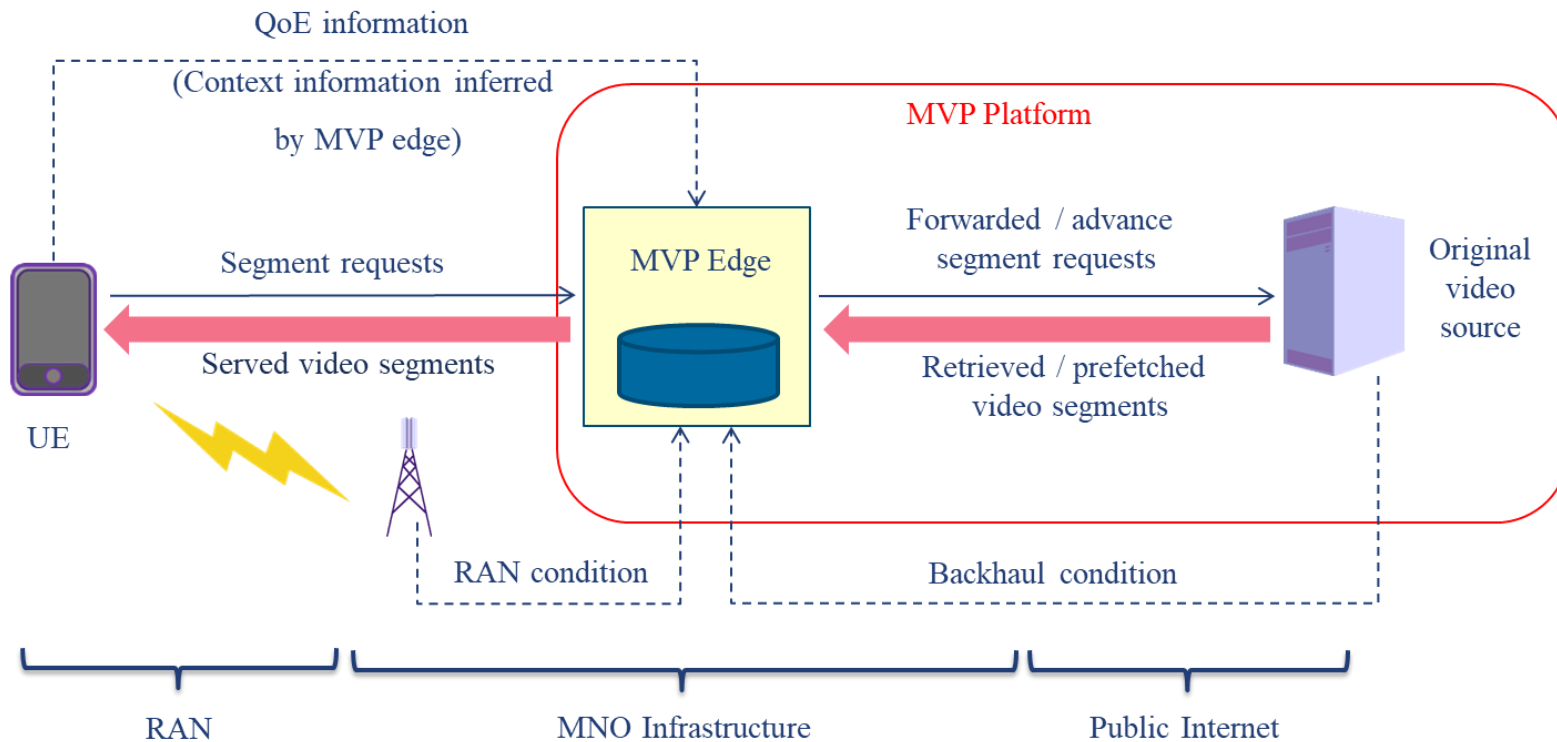(robots, cars, sensors, actuators, smart phones ………. driverless cars)

- Independently designed and developed 5G core network architecture – The **Flat Distributed Cloud (FDC)** and its supporting mechanisms
  - Fully compatible with **3GPP specification** (Release 15)
  - Context-awareness: the **Meta Data Protocol** (MDP)
  - Supporting dynamic **network slicing**, with creation time of new slice **within 2 minutes**
  - Supporting **over 1 million (**emulated) users by July 2018

UNIVERSITY OF SURREY
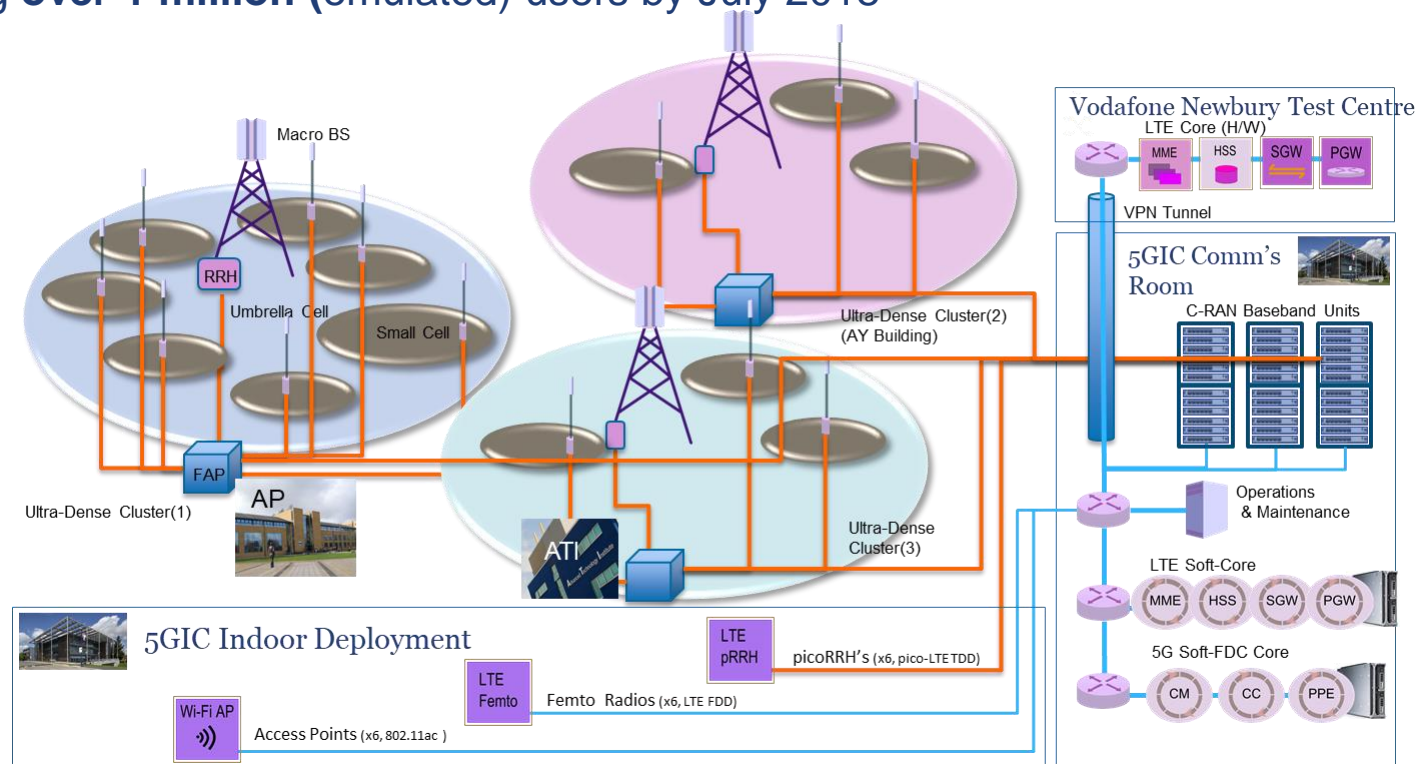
- **MVP**: Mobile edge Virtualisation with adaptive Prefetching

- **ETHLE**: Edge-based Transient Holding of Live Segment

- **World's first platform that enables QoE-assured 4K mobile video delivery at the Internet scale, without CDN support**

QoE information

(Context information inferred by MVP edge)

MVP Platform

Segment requests

MVP Edge

Forwarded / advance segment requests

Original video source

Served video segments

Retrieved / prefetched video segments

UE

RAN condition

Backhaul condition

RAN   MNO Infrastructure   Public Internet

- Featured at IEEE Communication Society (ComSoc) Technology News, September 2017
- Demonstrated at Mobile World Congress (MWC) in 2018

UNIVERSITY OF **SURREY**

- Our 5G vision started back in 2012, which led to the establishment of 5GIC jointly funded by the UK Government and the Industry
- The World's first innovation centre for 5G

Advent of new applications and requirements?

Noticing significant limitations in 4G?

Emerging technologies create opportunities to do things differently?

Time driven – About the right time to talk about 5G?

But how did it start in the first place?

Previous examples that made us desire 5G

- **Real-Time State Estimation (RTSE)** in smart power grids (2012-2013)
  - Streaming of measurement data created from PMU (Phasor Measurement Units) at individual substations in the field to remote PMU Data Centre (PDC) with "five 9's" reliability
  - E2E network latency <20ms → Allows active power control
  - E2E network latency <10ms → Allows feasible power failure detection
  - **4G radio NOT an option for assuring latency**
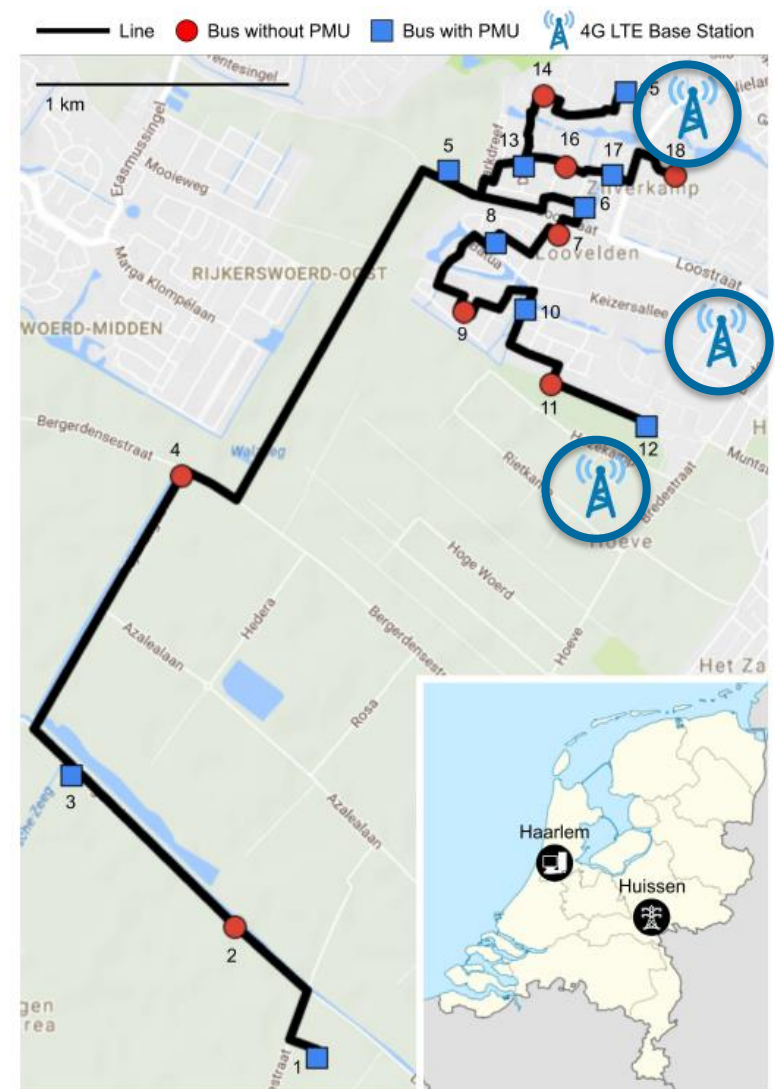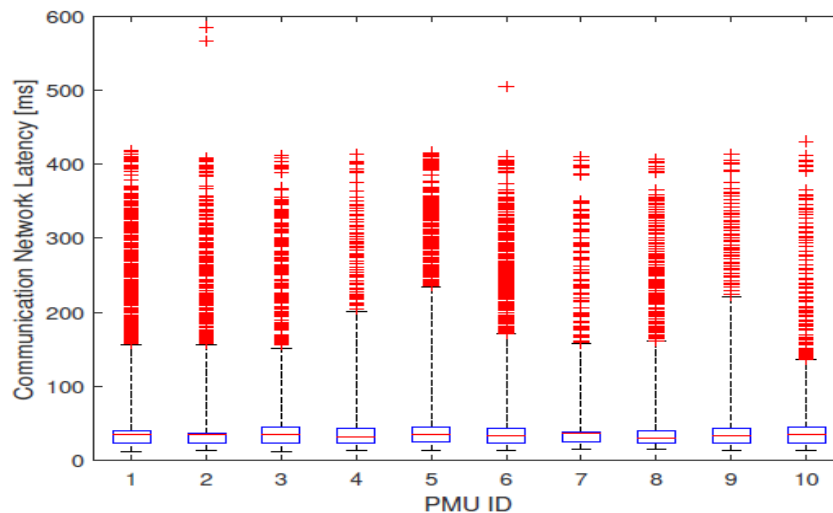
- **So where are we now?**

- **Moving forward – why do we need further design of future networks?**

  - **Applications & services that are not expected to be supported**

  - Minimising human intervention – Network automation

RXer   **TXer**

Sensual Info

Criticality of senses: 👁 > 👂 > 👆 > 👅 > 👃

Sensual Info

Actuation Info
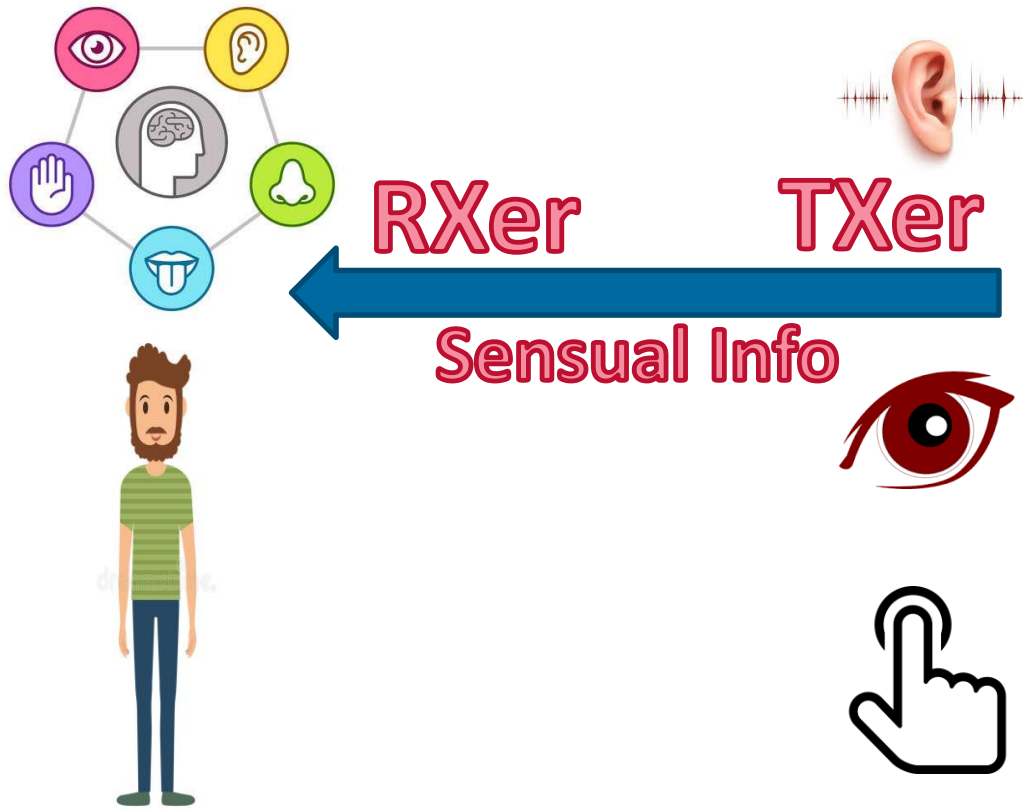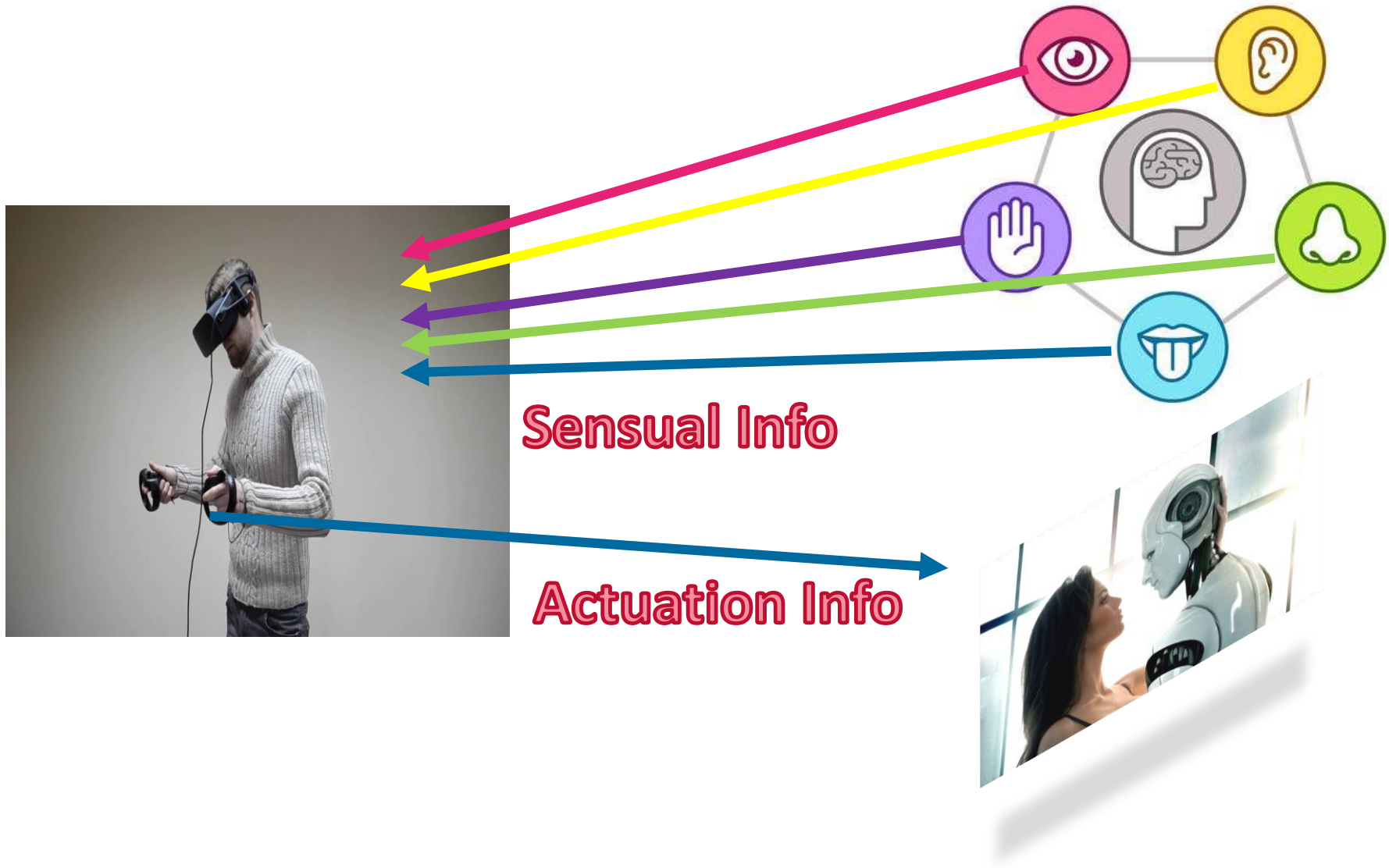
A Game of Data Rate Requirement

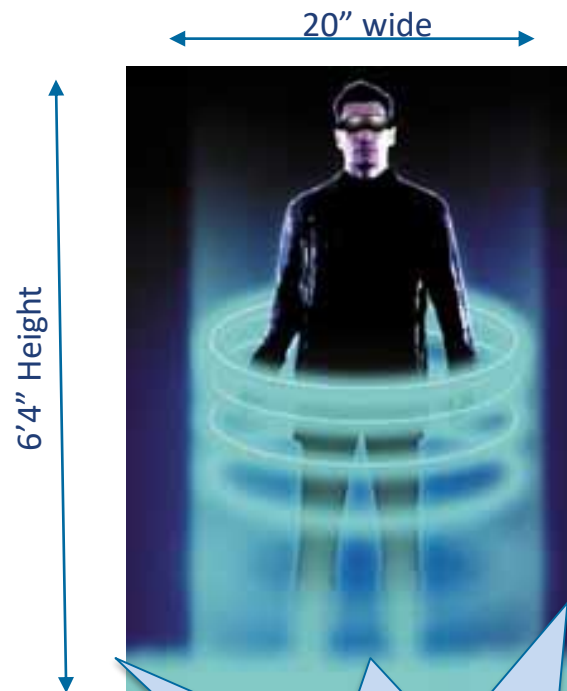|	Dimension	Bit Rate
Tile	4x4 inches	30 Gbps
Human	77x20 inches	4.62 Tbps

Colour, FP (full parallax), 30fps
Ref: N. Peyghambarian, University of Arizona

20" wide

6'4" Height

Other senses:
- **Touch**: ~20 – 50Mbps, for one hand around 1 Gbps
- **Smell**: Bitrate and latency: ?
- **Taste**: Inter-related to smell

How about data compression technologies?
Adding Latency!

- Still remember the evolution of 1-millisecond view on 5G latency?

1ms End-to-End → 1ms Edge-to-Edge (Core + Air interface) → 1ms Air Interface
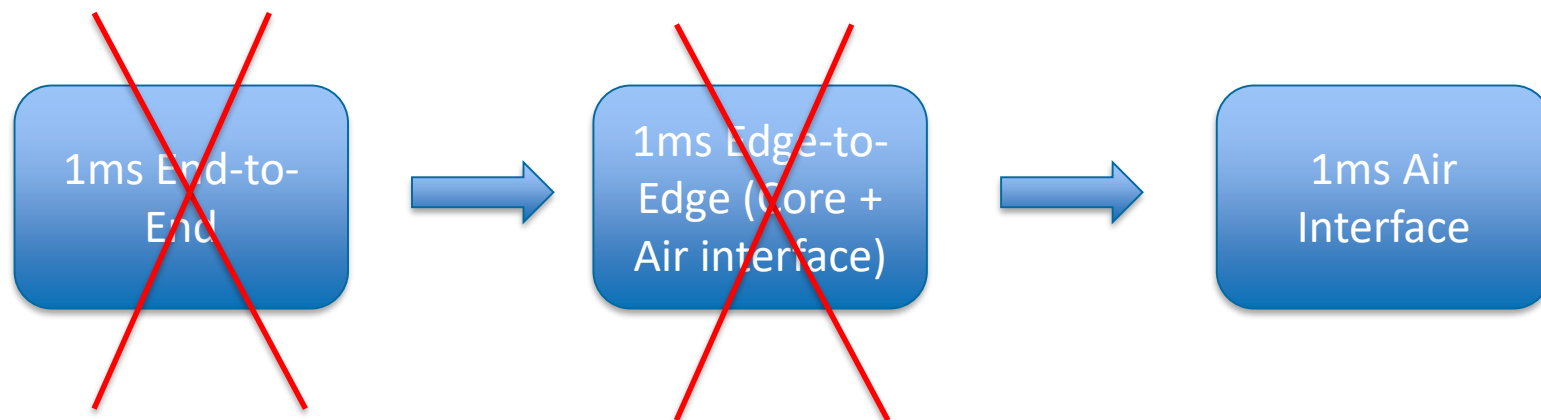
- How to satisfy latency requirements in real applications and **across the global Internet?**

- Sometimes latency bottleneck **does not** come from the network side!
  - Encoding/decoding, security/encryption etc.

Total accumulated Latency
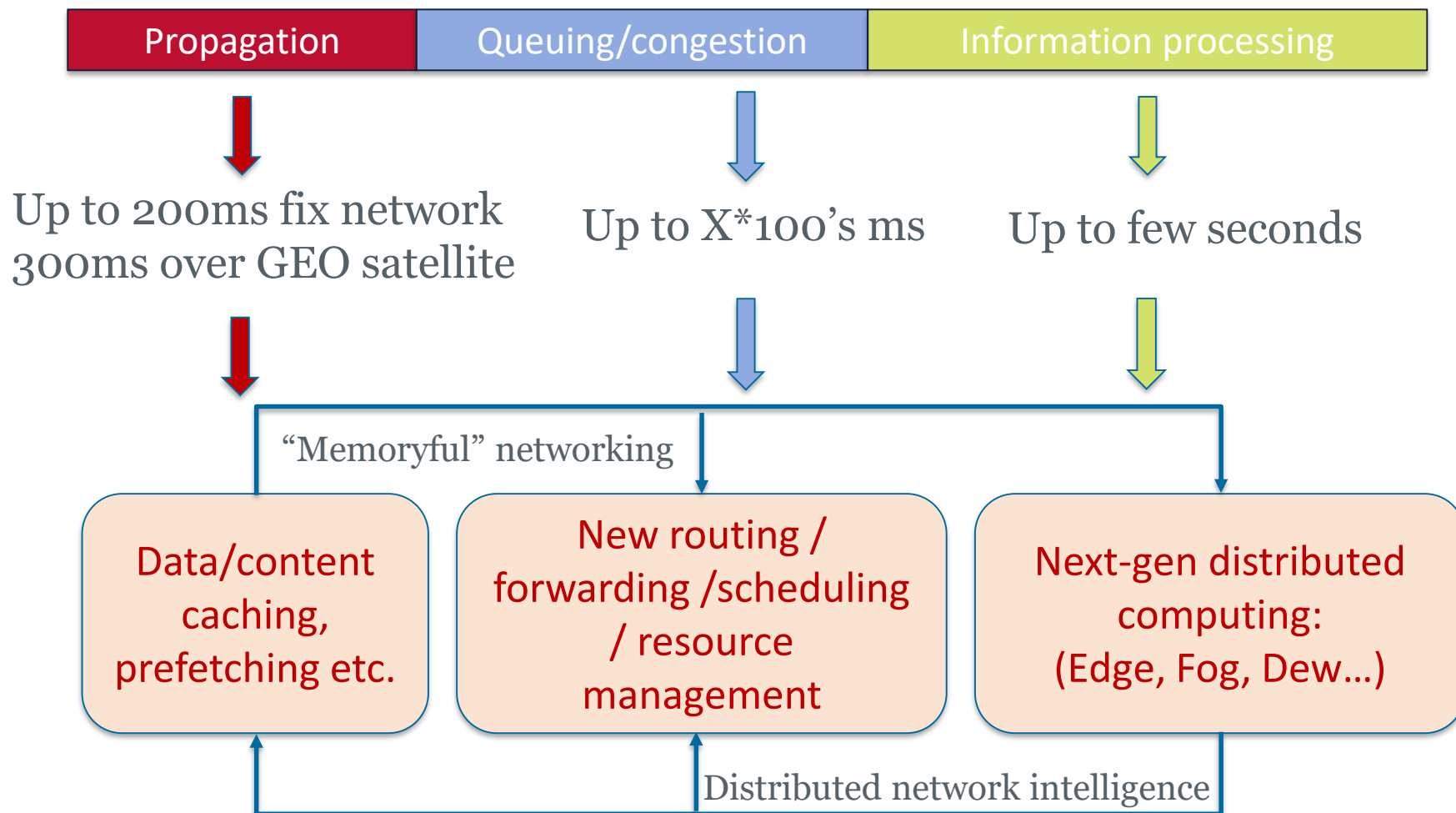
Propagation	Queuing/congestion	Information processing

Up to 200ms fix network 300ms over GEO satellite

Up to X*100's ms

Up to few seconds

"Memoryful" networking

Data/content caching, prefetching etc.

New routing / forwarding /scheduling / resource management

Next-gen distributed computing: (Edge, Fog, Dew…)

Distributed network intelligence

- **So where are we now?**

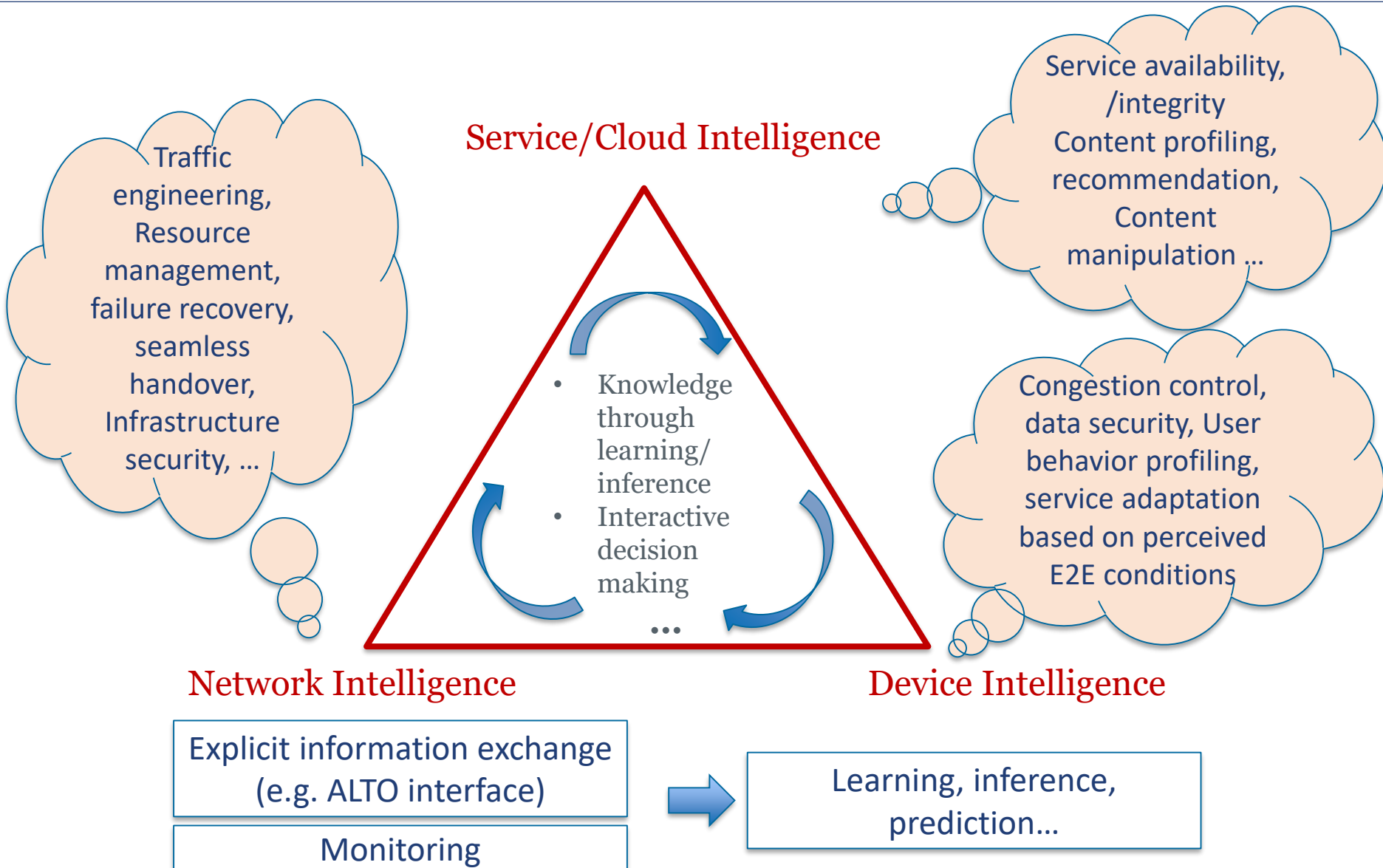- **Moving forward – why do we need further design of future networks?**

  - Applications & services that are not expected to be supported

  - **Minimising human intervene – Network autonomics**

The Intelligence Triangle
— When Everything Becomes Intelligent

Service/Cloud Intelligence

Traffic engineering, Resource management, failure recovery, seamless handover, Infrastructure security, …

Service availability, /integrity Content profiling, recommendation, Content manipulation …

- Knowledge through learning/ inference
- Interactive decision making

...

Congestion control, data security, User behavior profiling, service adaptation based on perceived E2E conditions

Network Intelligence

Device Intelligence

Explicit information exchange (e.g. ALTO interface)

Monitoring

Learning, inference, prediction…

Tussles between Stakeholders (Examples)

(1) Hey, I'd like to request a network slice for my service, and need control function of my own on this slice.

Service Providers

(2) Am I gonna lose the control of my own network resources at the end of the day?

Network operator

(2) Thank you for your kindness, but my content service is based on HTTPS!

Service (content) Provider

(1) Hey, I can choose to cache your content at my network edge! Your customer will benefit from substantially reduced latency in accessing them!

Network operator

- **Key issues**
    - How to share the control power between heterogeneous stakeholders while retaining appropriate balanced controllability between them?
    - Security/privacy issues in delivering the service?

Our Vision with Three Requirements/Principles

Support flexible embedding of third-party, vertical-specific intelligence as virtual network functions (VNFs)
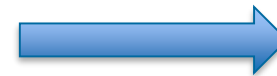
⭐ SP Benefits

- Empowered service capability
- Reduced TCO
- Retaining security/privacy

Being able to retain effective control on own network resources (communication, computing, storage…)

⭐ Operator Benefits

- New revenue by renting virtual resources
- Retaining controllability

No exposure of internal complexity on the network side to user devices unless it is necessary
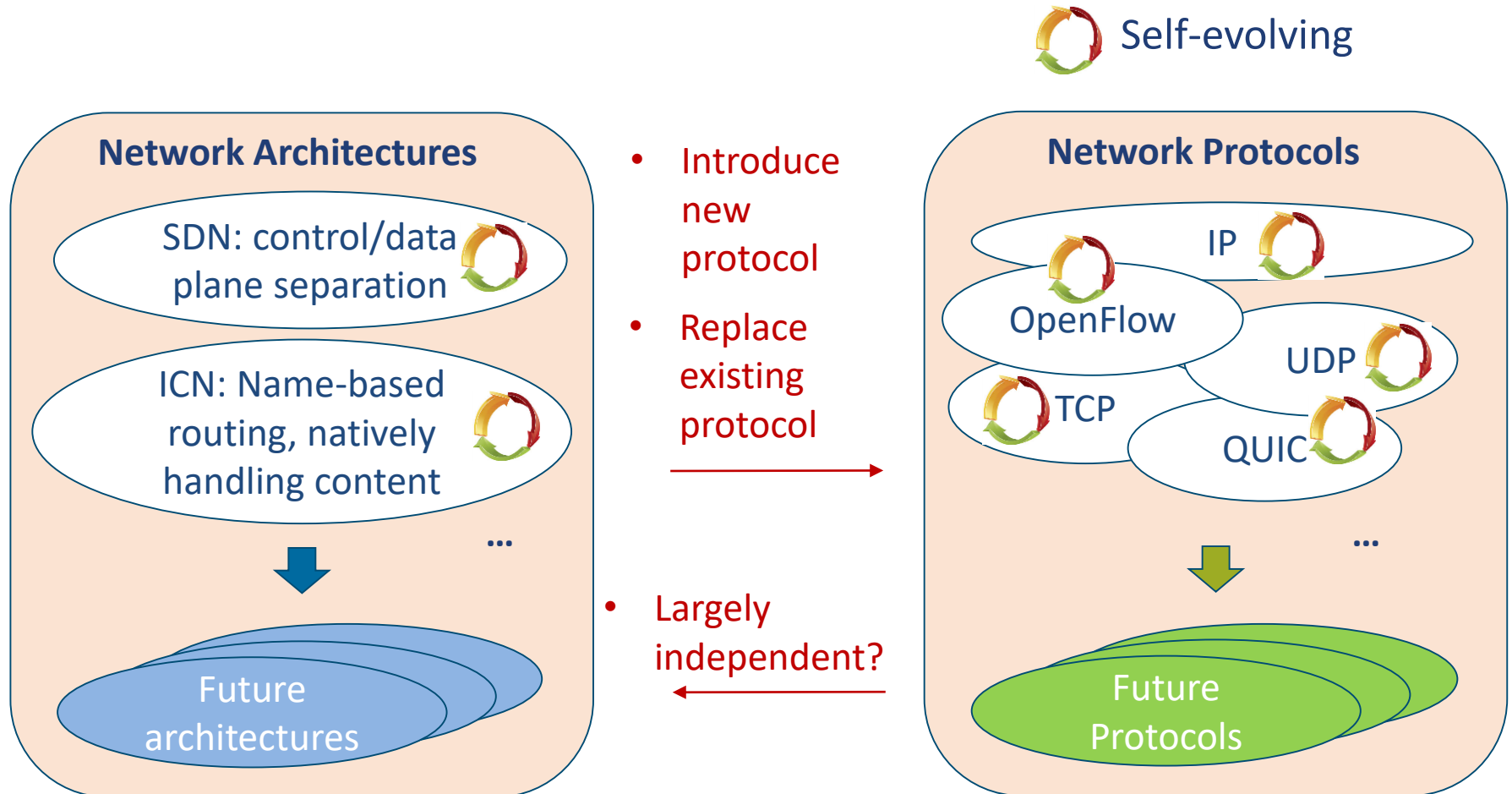- **Smart network edge**

⭐ User Benefits

- Simplicity
- Intelligence on the device side only dedicated to applications rather than network

The Dilemma of Replacing TCP/IP?

Let's differentiate the (r)evolutions of <u>network architectures</u> from <u>network protocols</u> which are not always coupled together!

Self-evolving

Network Architectures
- SDN: control/data plane separation
- ICN: Name-based routing, natively handling content
- ...
- Future architectures

- Introduce new protocol
- Replace existing protocol
- Largely independent?

Network Protocols
- IP
- OpenFlow
- UDP
- TCP
- QUIC
- ...
- Future Protocols

- Developing a **new architecture** for digital infrastructures, composed of **highly-dynamic network functions** that are collectively able to **adapt to the real-time requirements** of future digital services.

- Creating a new **autonomic framework** for digital infrastructure to equip the nodes of the infrastructure network with the ability to **understand** their state, **detect and diagnose** disruptions to service, and take **autonomous** actions.

- Implementing approaches for the **successful integration** of these technologies **within the business functions** with an aim to **improve service assurance** and organizational value.

http://www.ng-cdi.org/

Thank You!