New IP: Going beyond the Limits of the Internet

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IEEE Globecom 2019, Big Island, USA
Dec 9-13, 2019

Who should care about New IP?

FUTUREWEI Technologies

Technology and Equipment

Technology Vendors

Carriers and Service Providers

Scientists and Engineers

Applications, Industry Verticals, Public Services

Industrial Internet

Sport and Entertainment

Education and Healthcare

Agenda

1

Network 2030

- ITU-T Initiative
- Driving Forces

2

Current IP

- Limitations
- Challenges

3

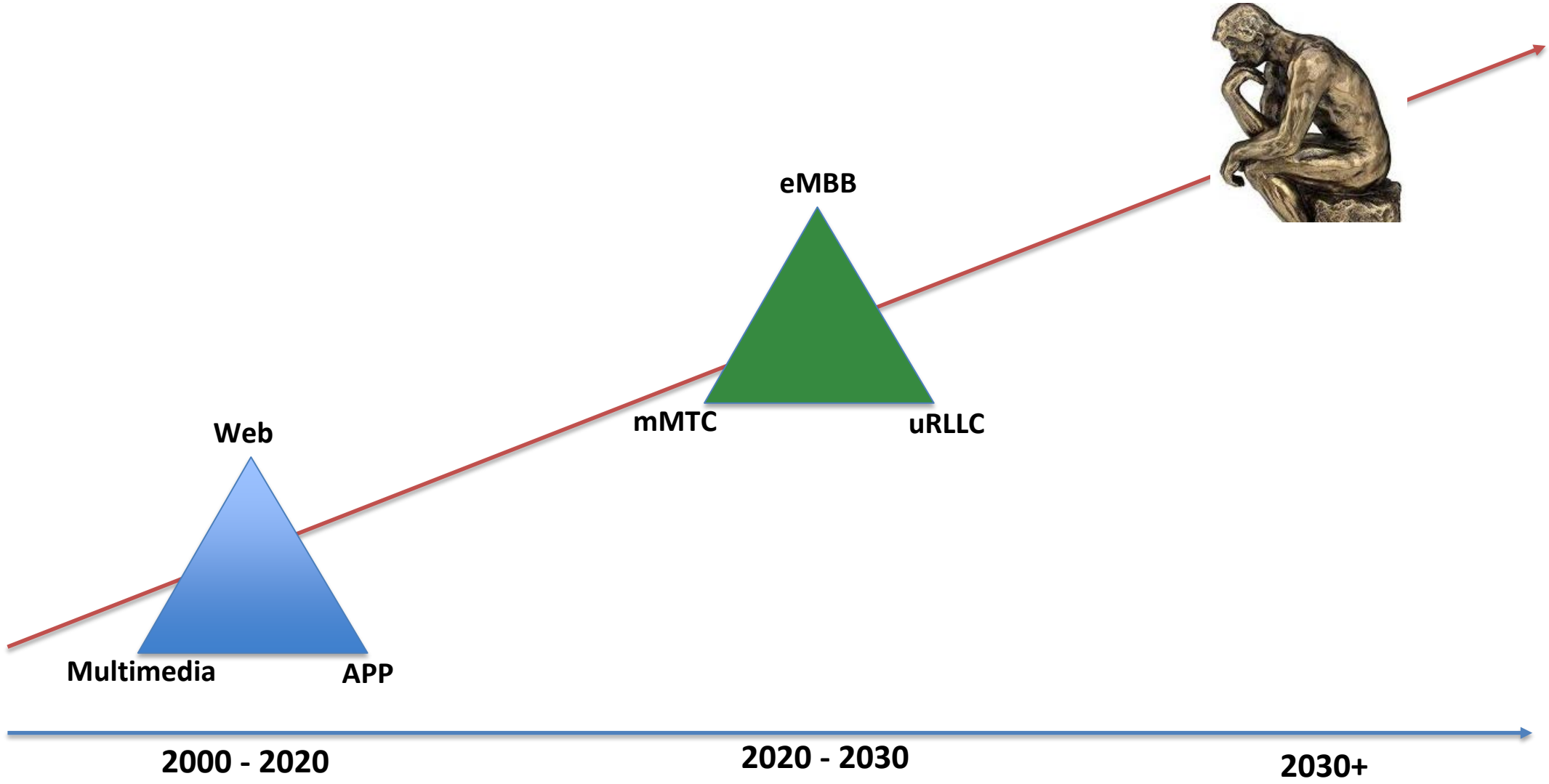
New IP

- Motivation
- Innovation

4

Summary

What will be in the year 2030 and beyond?



ITU-T Focus Group on Network 2030

Identify **future use cases** and new requirements

Study **new capabilities** of networks for the year 2030 and beyond

Explore **new concepts,** principles, mechanisms, and architectures

Review Protocol Stack, and outline **future directions**

https://www.itu.int/en/ITU-T/focusgroups/net2030/Pages/default.aspx

Establish

July 16 – 27, 2018
Geneva

1st Meeting

October 2 – 4, 2018
New York

2nd Meeting

December 18 – 21, 2018
Hong Kong

3rd Meeting

February 18-20, 2019
London

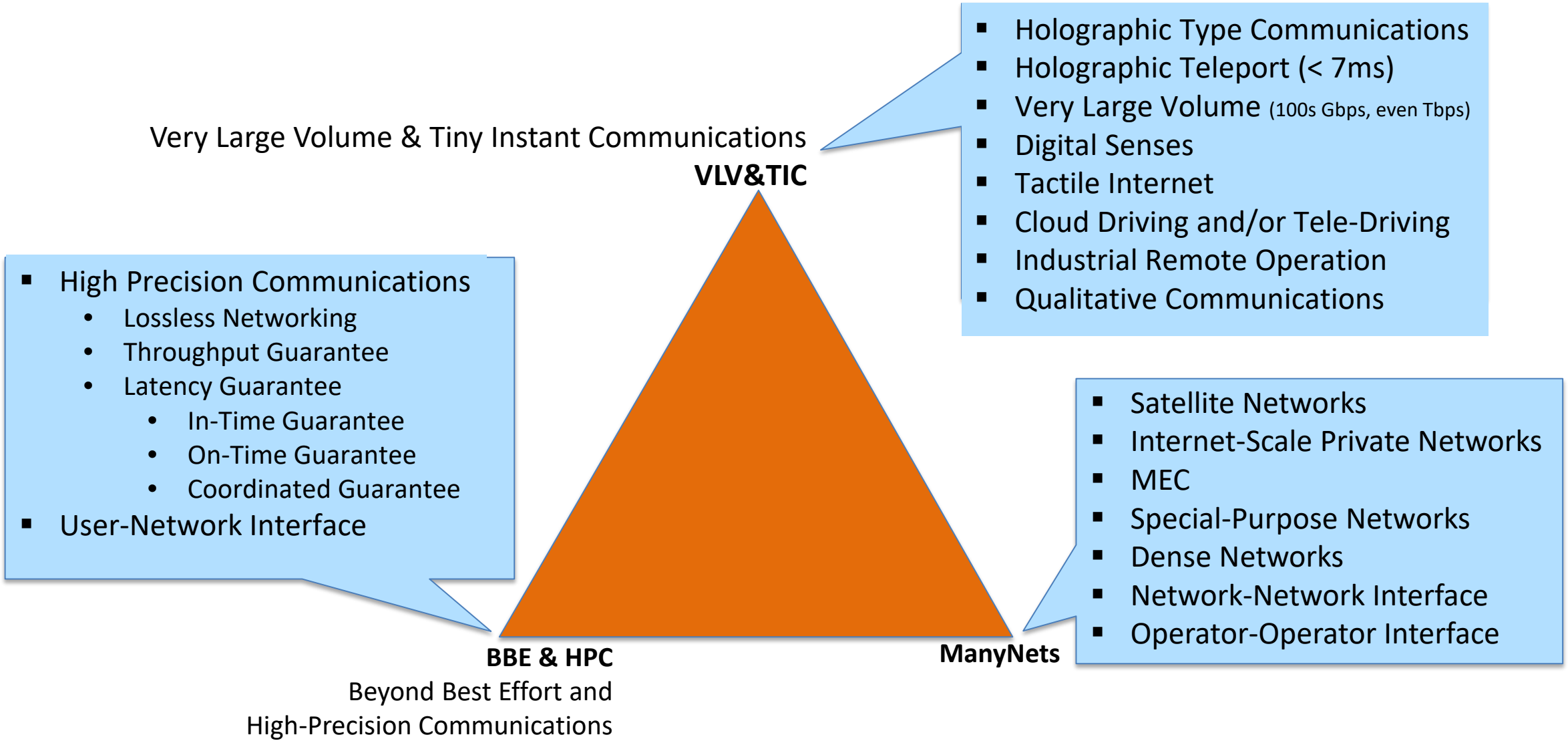
4th Meeting

May 21-23, 2019
St. Petersburg

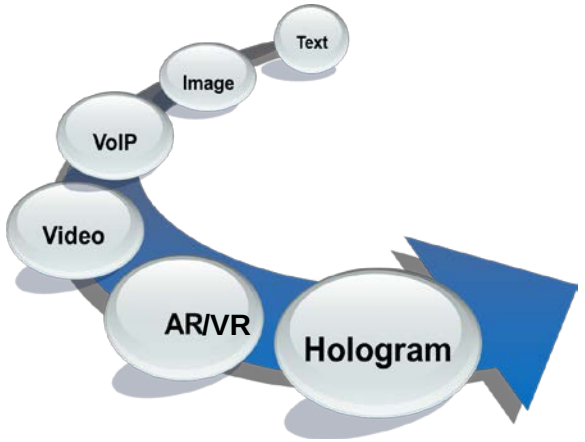
5th Meeting

October 14-18, 2019
Geneva

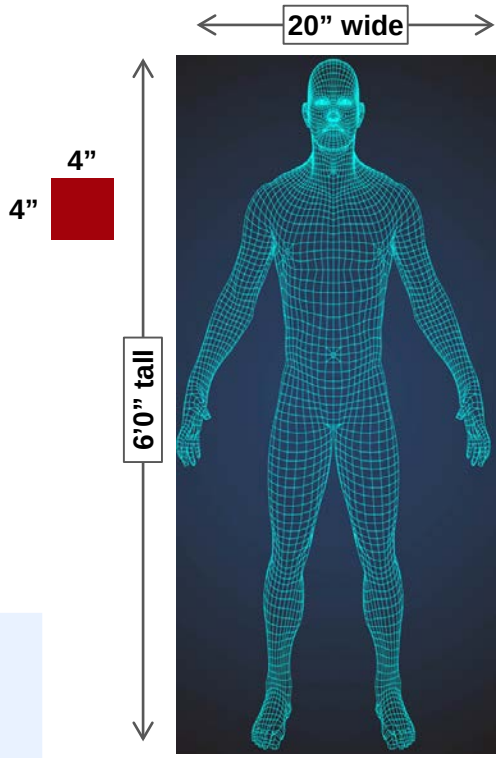
Market and Business Drivers for the Future



Holograms and Holographic Type Communications



	Dimensions	Bandwidth
Tile	4 x 4 inches	30 Gbps
Human	72 x 20 inch	4.32 Tbps



(reference: 3D Holographic Display and Its Data Transmission Requirement, 10.1109/IPOC.2011.6122872), derived from for ‘Holographic three-dimensional telepresence’; N. Peyghambarian, University of Arizona)

Raw data; no optimization or compression. color, FP (full parallax), 30 fps

Throughput goes up

4K/8K HD	band width	AR/VR	band width	Hologram
35Mbps~140Mbps	▶	25Mbps~5Gbps	▶	4 Tbps~10 Tbps

Real-Time Streaming: Latency stays low

4K/8K HD	delay	AR/VR	delay	Hologram
15 ms ~ 35 ms	▶	5 ms ~ 7 ms	▶	5 ms ~ 7 ms

Motion-to-photon time: 20 ms

Synchronization of parallel streams

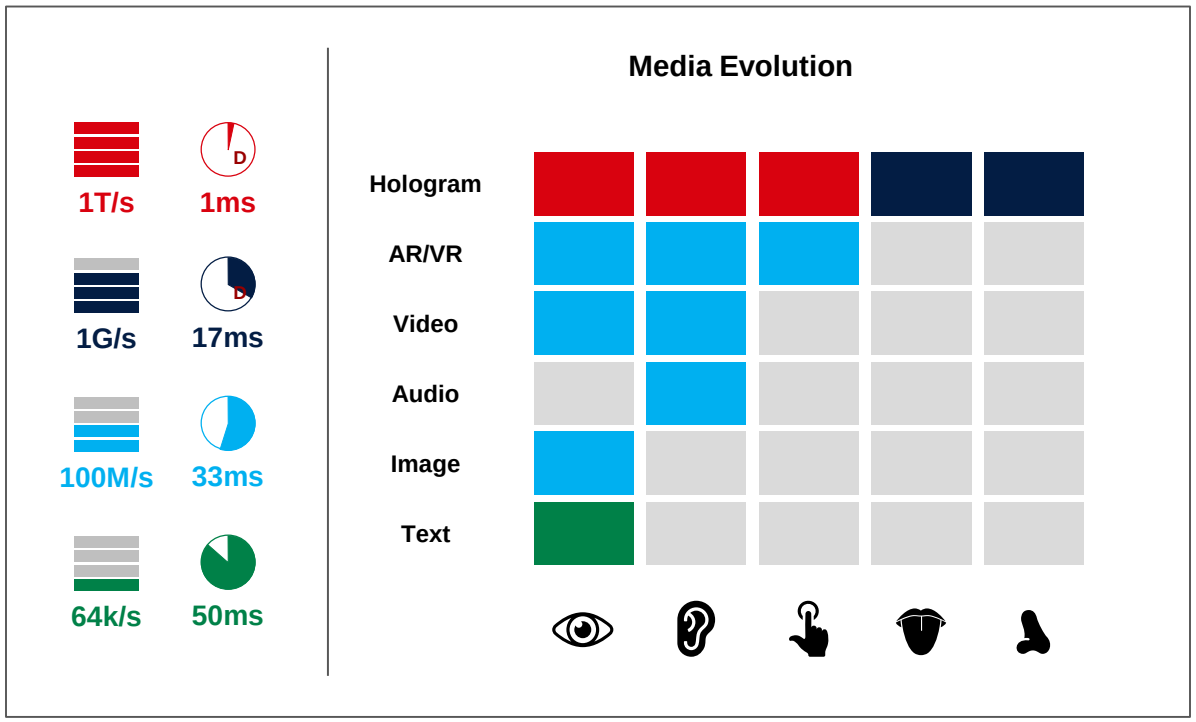
4K/8K HD	streams	VR/AR	streams	Hologram
Audio/Video(2)	▶	Multiple tiles (12)	▶	~thousands (view-angles)

360 degrees of view
6 degrees of freedom

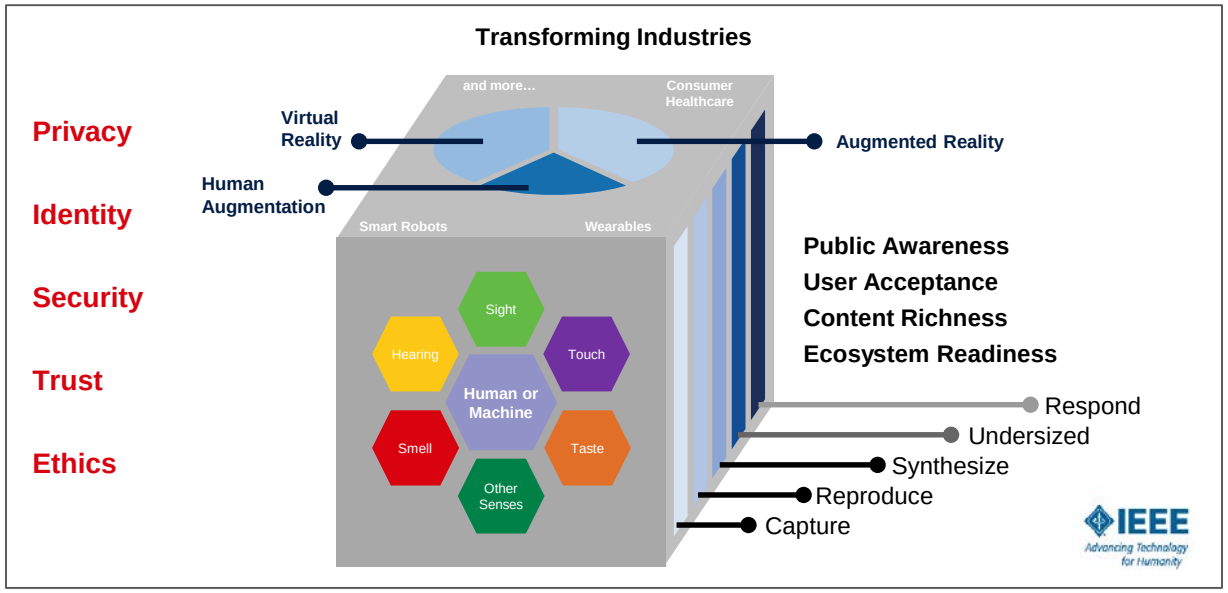
Attaching Digital Senses to Holograms







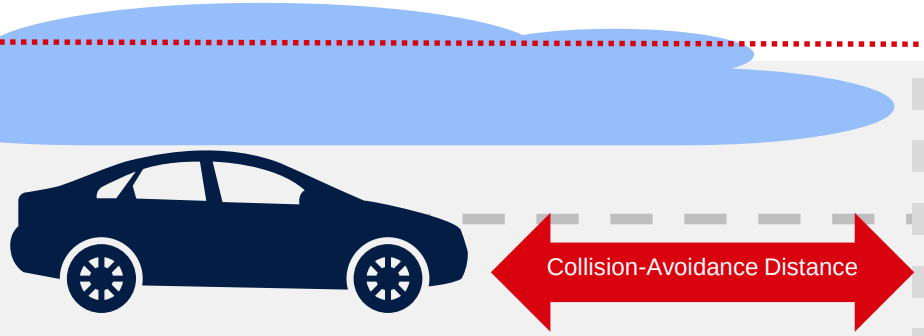
IEEE Digital Senses Initiative
Coverage Model



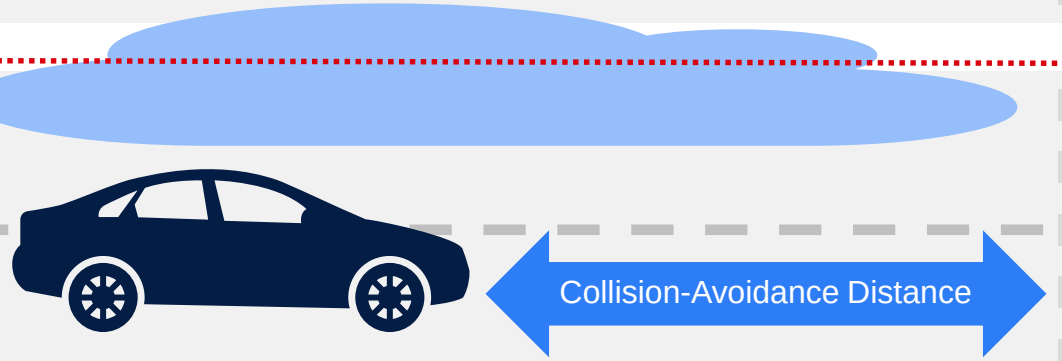
Cloud Driving: Latency and packet loss are crucial

FUTUREWEI Technologies

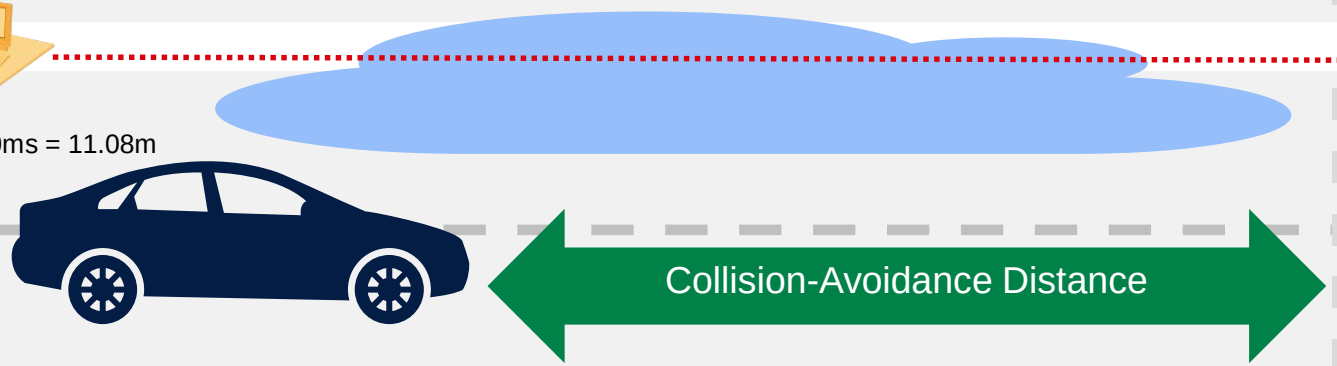
5 km/hour = 1.4m/sec.
Crash-Avoidance distance = 1.4m/sec x 660ms = 0.92m



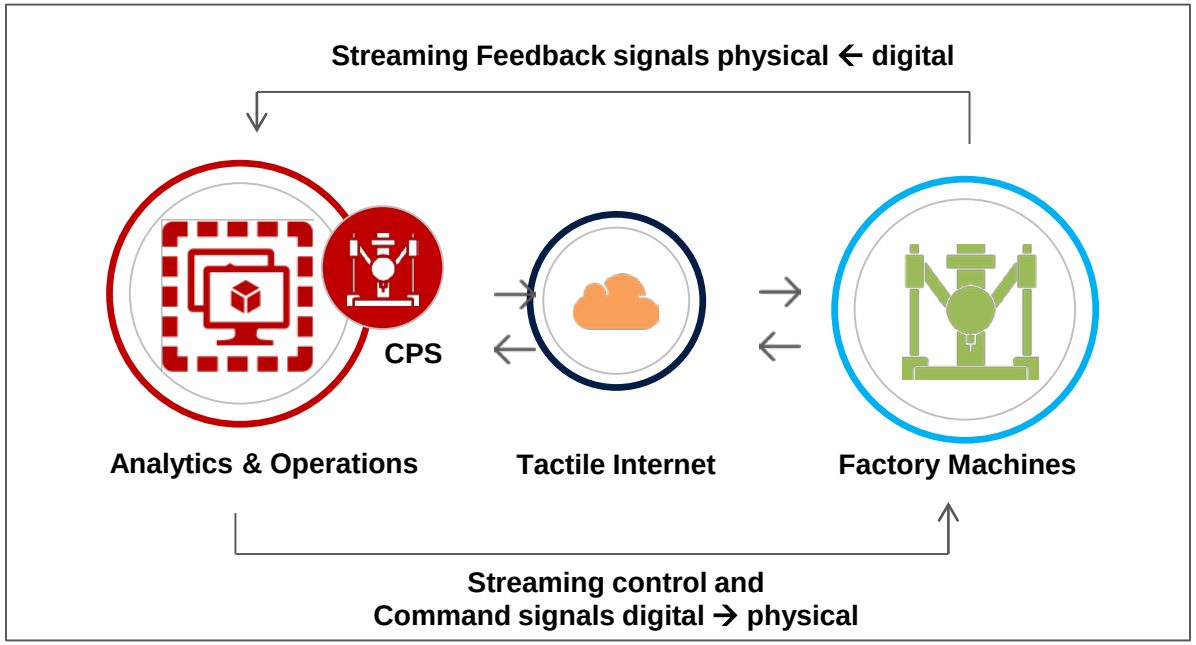
30 km/hour = 8.4m/sec.
Crash-Avoidance distance = 8.4m/sec x 660ms = 5.54m

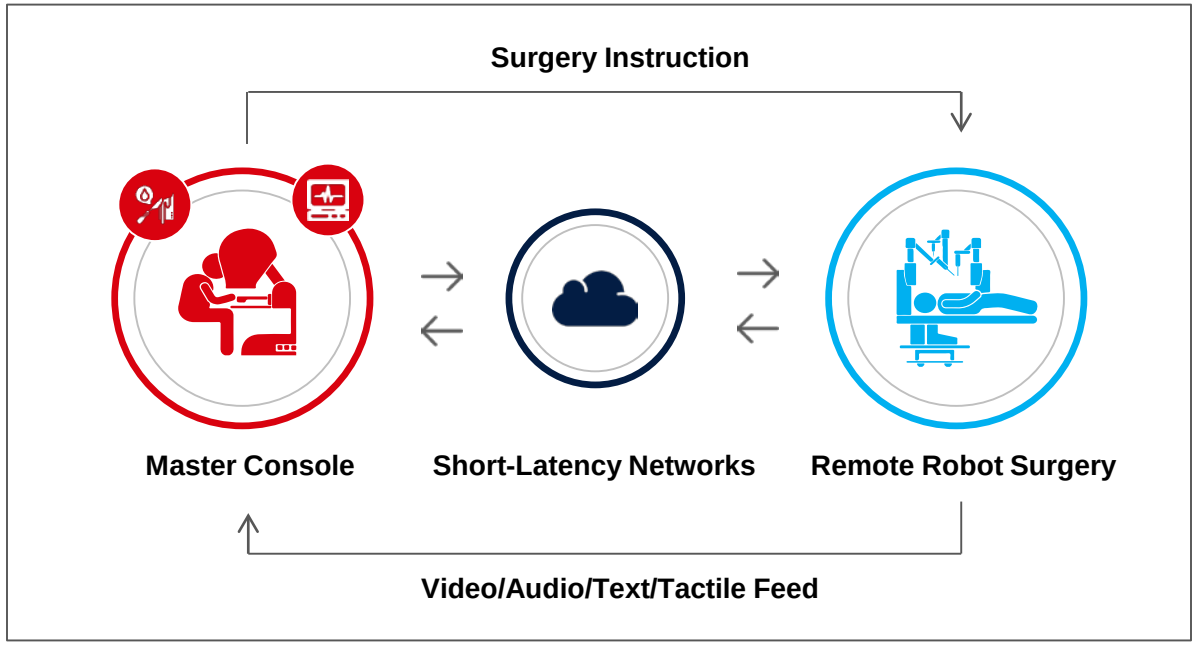


60 km/hour = 16.8m/sec.
Crash-Avoidance distance = 16.8m/sec x 660ms = 11.08m



Tactile Internet and Short-Latency Networks

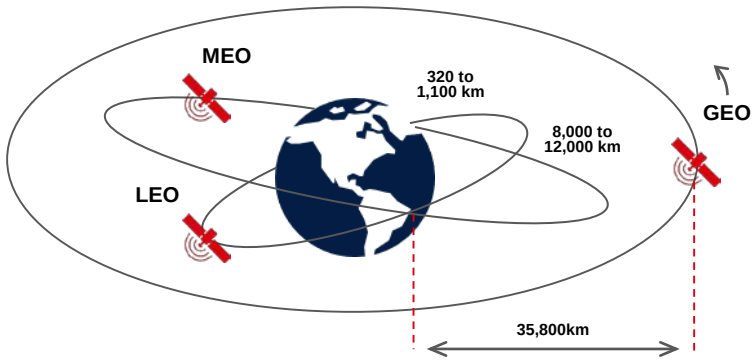




- **Ultra-low latency**
  Sub-millisecond to 5 milliseconds.
- **Ultra-low loss**
  Loss of packets is almost intolerable
- **Ultra-high bandwidth**
  From 360-degree video to holograms. VR feed: 5 Gbps; Holograms: Tbps
- **Stringent synchronization**
  Different human-brain reaction times to different sensory inputs (tactile: 1ms, visual: 10ms, or audio: 100ms). Hence real-time feedback from different inputs must be synchronized accordingly.
- **Differentiated prioritization levels**
  Prioritizing streams based on their immediate relevance.

Space Internet

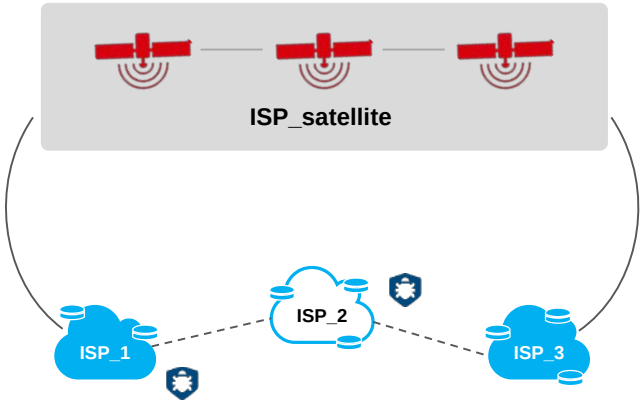
internet capabilities with satellites on earth orbits



Geosynchronous Earth Orbit
GEO: 35,800 km

Medium Earth Orbit
MEO: ~10,000 km

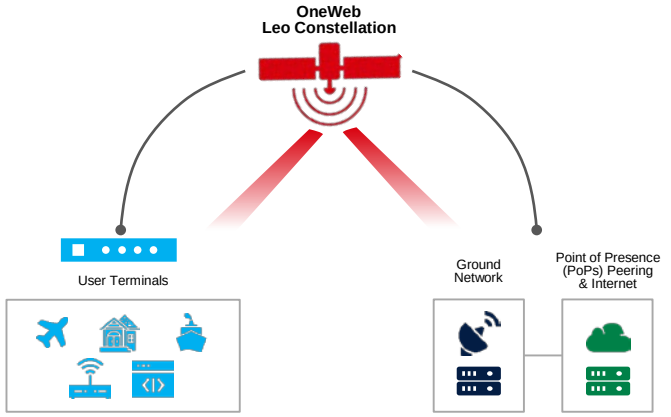
Low Earth Orbit
LEO: ~1000 km



Near future use

- Internet for rural areas
- Emergency relief
- High-speed aviation and navigation broadband
- Cross-border transmission

OneWeb launched 6 airbus satellites to LEO in Feb. 2019.



Throughput 400mbps

Latency 40ms

Stream HD video at 1080p

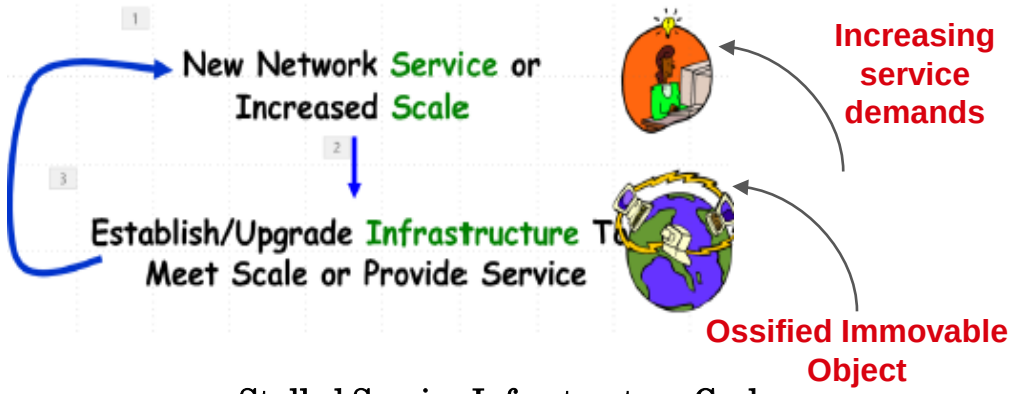
Company	Support	No. of Satellites
Starlink	SpaceX	4K by 2019, then 12K
OneWeb	Softbank	650 by 2019
O3Nb	Virgin group, SES	400
CASIC	China	300 (54 trial)

* Data comes from the Internet, not yet verified

Infrastructural Changes: Fragmentation and Death of Transit

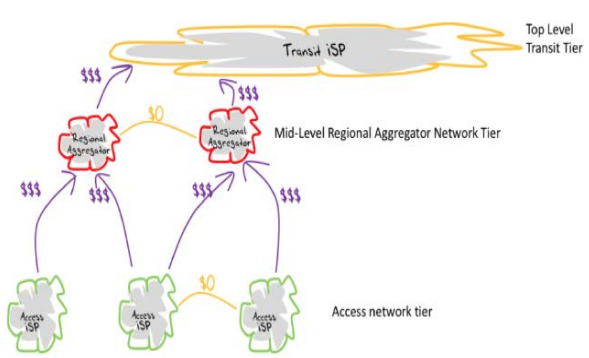
FUTUREWEI Technologies

The Fragmentation of the Internet

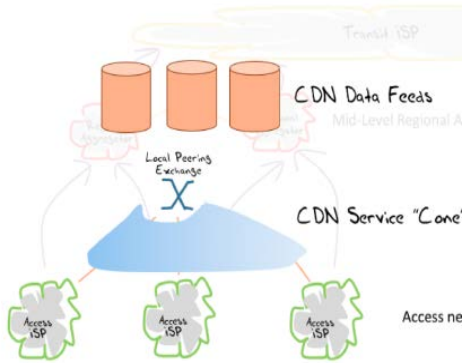


Stalled Service-Infrastructure Cycle

Disappearing Internet Transit



Original Infrastructure



Today's Infrastructure

New Services and Eliminating Ossification

Demands that the Internet cannot satisfy are made feasible by separate purpose-built bypass networks (administered separately).

By its very nature, ManyNets world cannot ossify, since new demands can always be satisfied with new networks.

From 'ex uno pluria'

Source: Mostafa Ammar, Keynote Speech at 3rd ITU-T Workshop on Network 2030, London, UK, Feb. 2019

Shrinking Public Transits and Growing Private Transits

If content is now delivered via CDNs to users via discrete service cones…

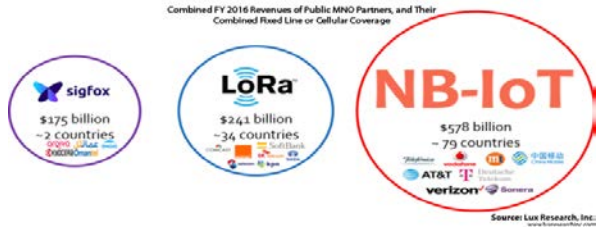
If users don't send packets to users any more…

If there is no universal service obligation…

From 'The Death of Transit and Beyond'

Source: Geoff Huston, Keynote Speech at 2nd ITU-T Workshop on Network 2030, Hong Kong, Dec. 2018

ManyNets: Embracing Diversity, Variety, and Economy



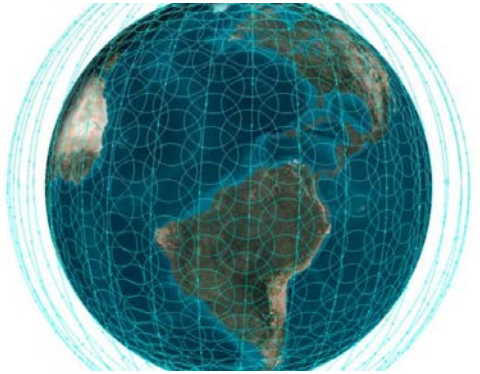
Spread Networks

FirstNet®

Non-IP Networks
(Growing market segment)

Private Global Backbones
(Death of Internet Transit)

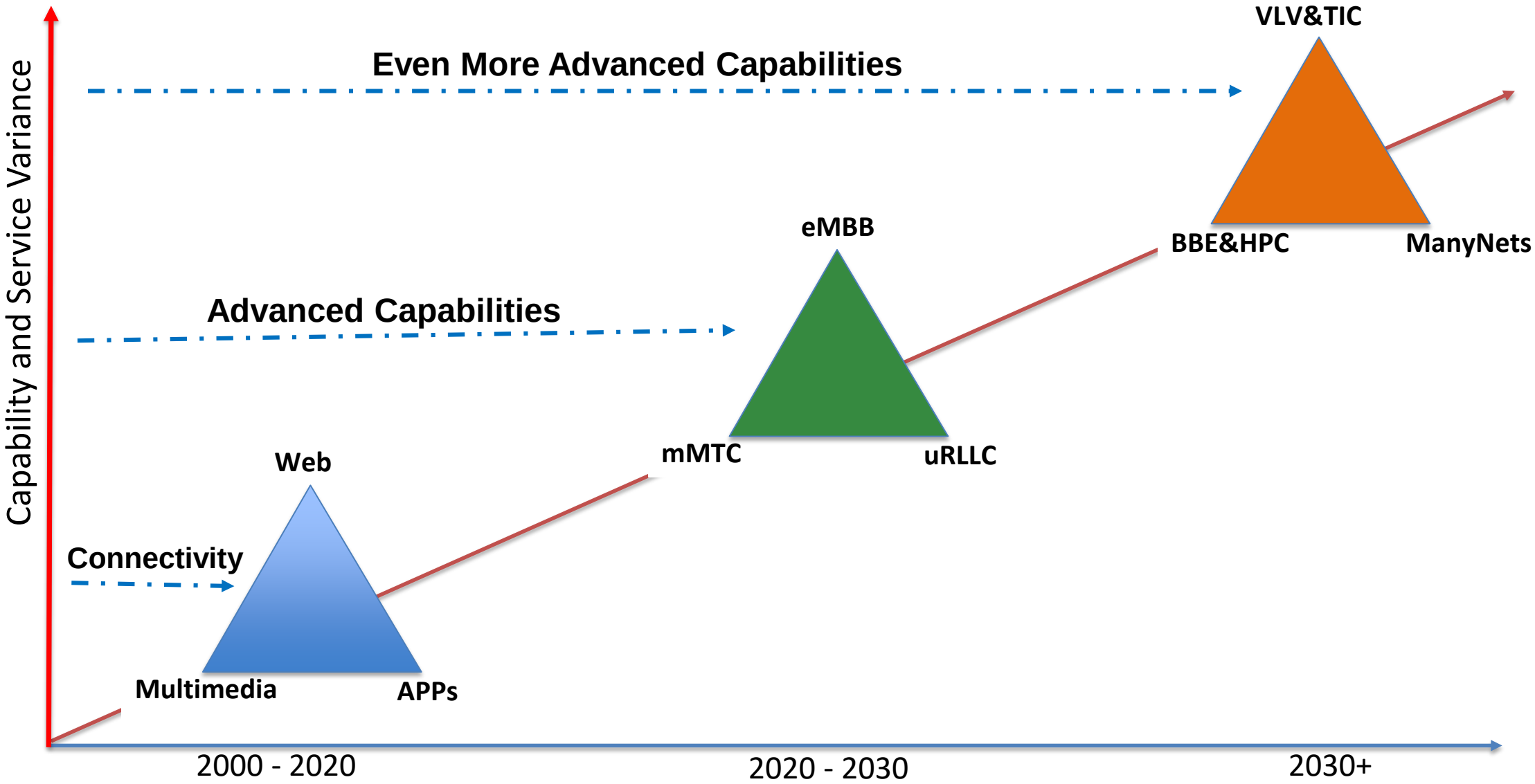
OneWeb



Starlink

Emerging Satellite Constellations
(Global Broadband connectivity for 4 billion people who are not connected to any network today)

Past, Present and Future: Market Drivers



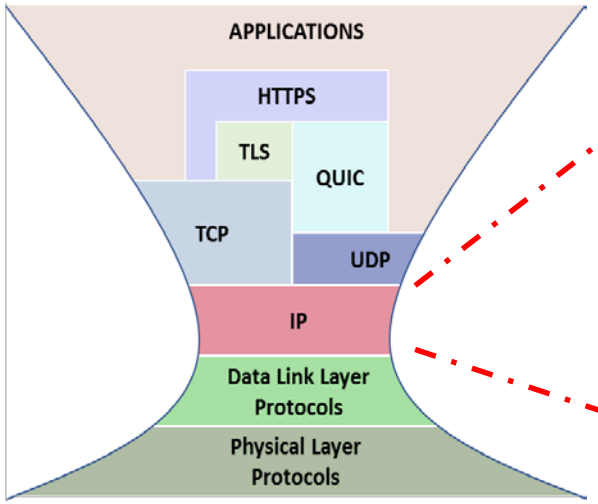
Current IP

Limitations

Expectations

Overview

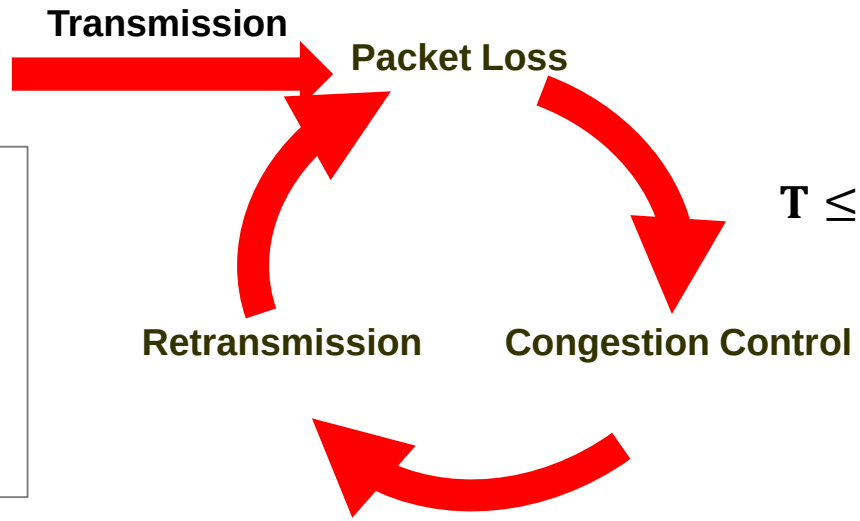
Statistical Multiplexing



Capabilities and and Services

- Best Effort (default and mostly used)
- DiffServ (on a per-hop basis)
- Traffic Engineering (mainly in MPLS)
  - Traffic Steering (Explicit Path)
  - Bandwidth Guarantee
  - Fast Re-Route

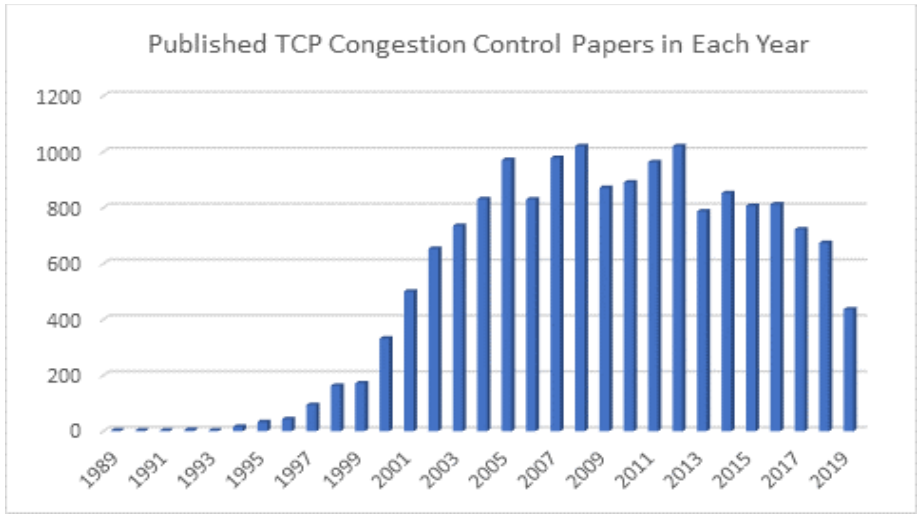
Packet switching:	2019-1961 = 58 years
TCP/IP (Cerf's paper):	2019-1974 = 45 years
IPv4 (RFC 791):	2019-1981 = 38 years
IPv6 (RFC 1883):	2019-1995 = 24 years
MPLS (RFC 3031):	2019-2001 = 18 years



Cerf-Kahn-Mathis Equation

$$\mathbf{T} \leq \mathbf{min}(\mathbf{BW}, \frac{\mathbf{WindowSize}}{\mathbf{RTT}}, \frac{\mathbf{MSS}}{\mathbf{RTT}} \times \frac{\mathbf{C}}{\sqrt{\boldsymbol{\rho}}})$$

Meeting Network Capacity with Traffic Demand

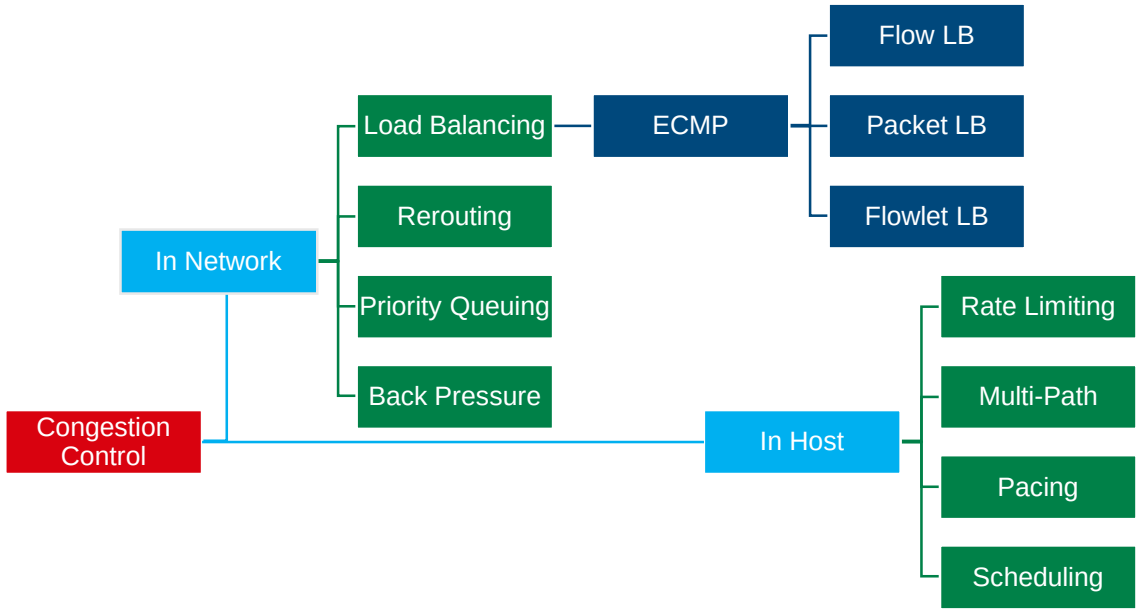


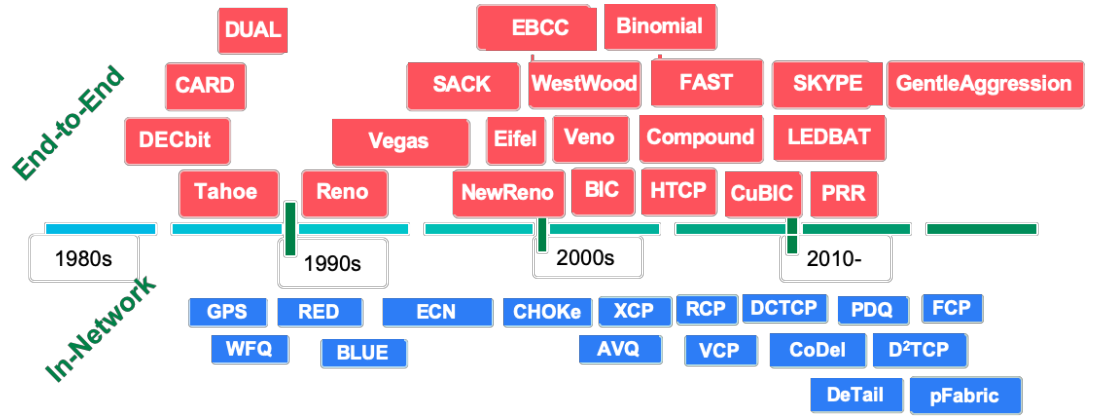
See ACM SIGCOMM 2019 Keynote (Mark Handley) for his personal achievements

- It is an eternal and never-stopping topic in ACM Sigcomm
- Google Scholar returns 13,200 publications on “TCP Congestion Control”
- No one size fits all

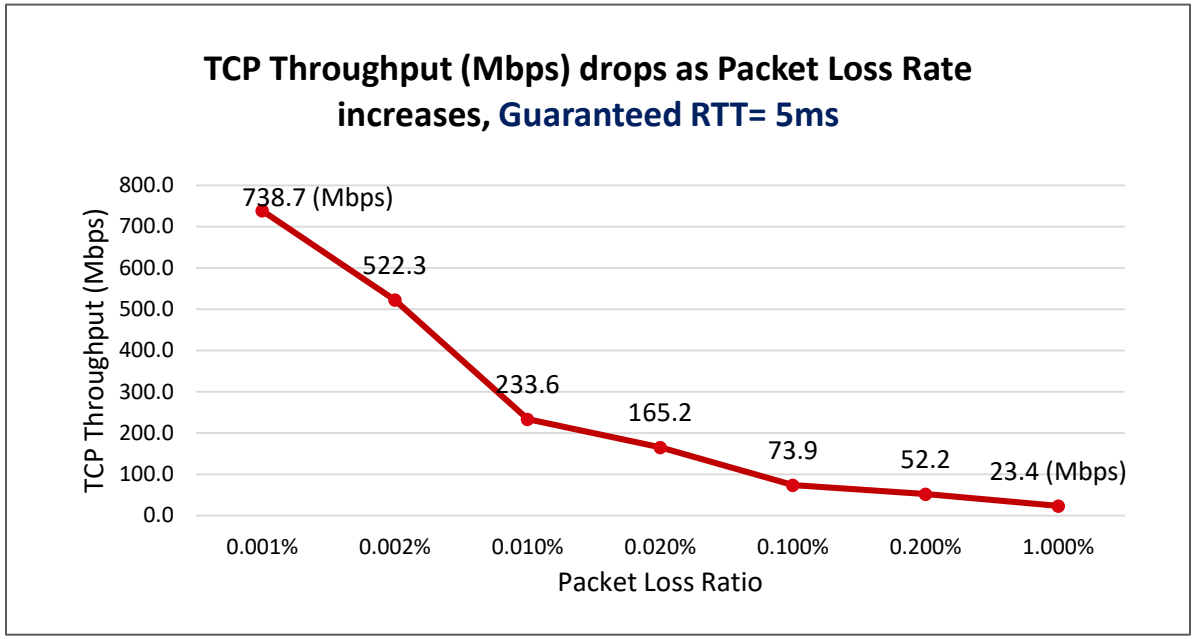
Time to read 36 years

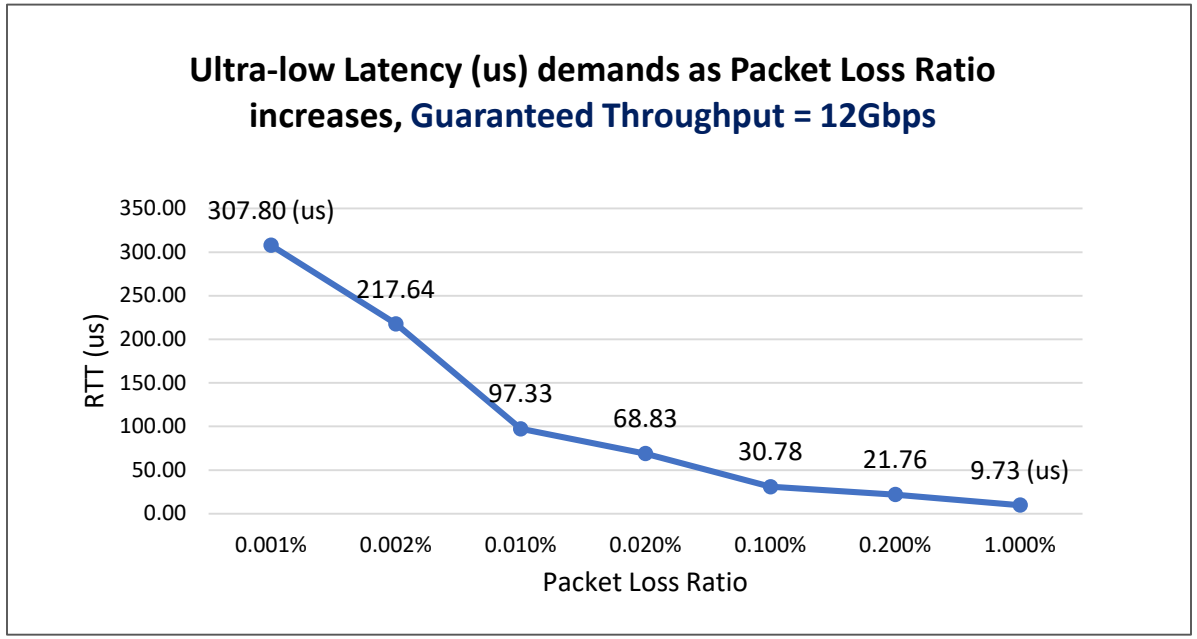
Read one paper a day. 13200/365





Extrapolation from Cerf-Kahn-Mathis Equation





- If you lose 1 packet per 10,000 packets, your latency is 0.1 ms in order to yield a throughput of 12 Gbps
- The result may vary with CPUs, Links, Buffers, etc, but throughput, latency and packet loss are coupled closely together
- You can't make omelet without breaking eggs!

- *improvements exist, but the nature of the correlation between throughput, packet loss and latency keeps similar.*

IP/MPLS in Mobile Backhaul Networks

No guarantee on E2E throughput and latency by current TCP/IP

No good enough KPIs on network slicing for mission-critical applications

Inefficient use of protocols

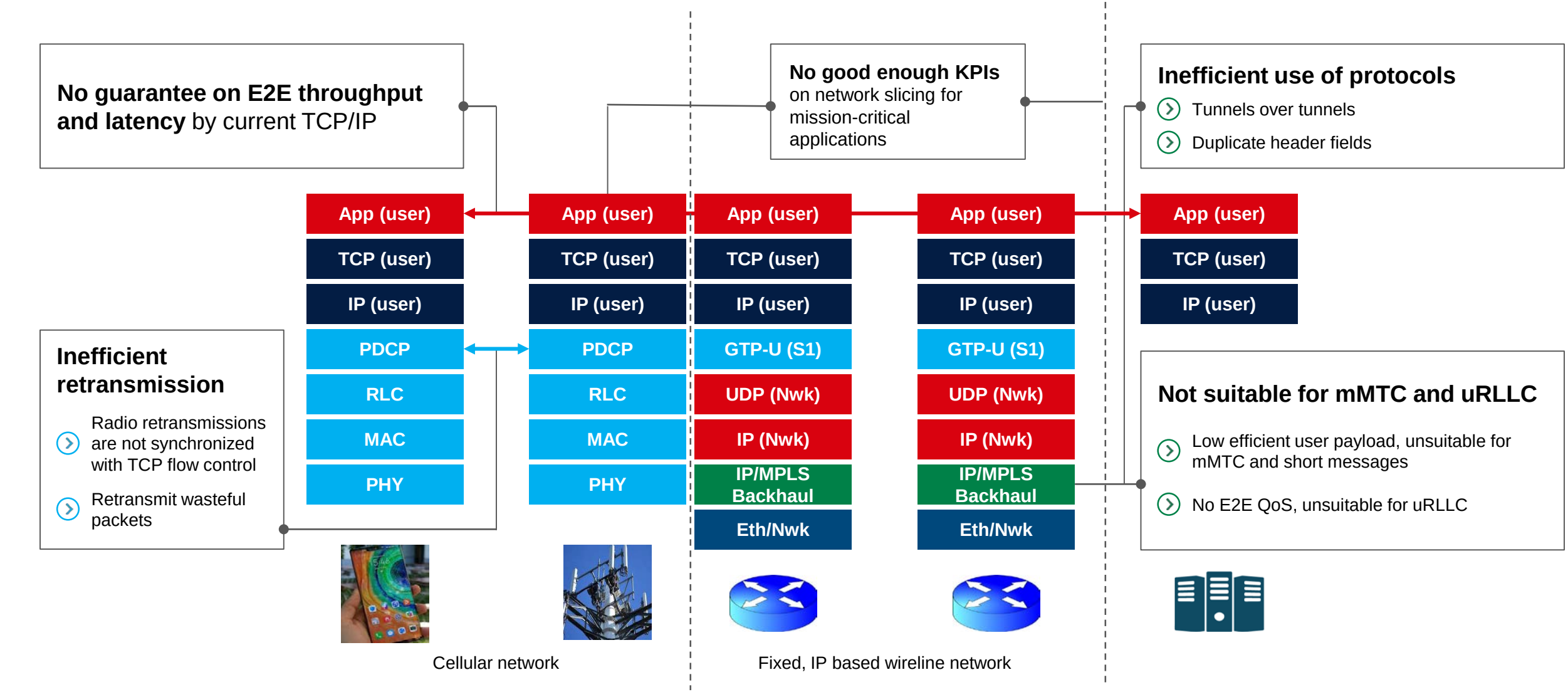
- Tunnels over tunnels
- Duplicate header fields

Inefficient retransmission

- Radio retransmissions are not synchronized with TCP flow control
- Retransmit wasteful packets

Not suitable for mMTC and uRLLC

- Low efficient user payload, unsuitable for mMTC and short messages
- No E2E QoS, unsuitable for uRLLC



Expectations from New IP

- The current Internet is essentially of best-effort, but future applications require high-precision KPIs on throughput, latency and packet loss for industrial manufacturing, control, automation, and machine-to-machine communications

- The current Internet is subject to the Cerf-Kahn-Mathis equation, but the future applications require:
  - Throughput should be linearly proportional to bandwidth: $T = c_1 \times BW$
  - Latency should be linearly proportional to physical distance: $L = c_2 \times D$

- New IP should accommodate ManyNets and provide for integration and convergence of all different types of networks, especially provide for integration of satellite networks and the terrestrial Internet

New IP: A Progressive Way to Evolve the Internet

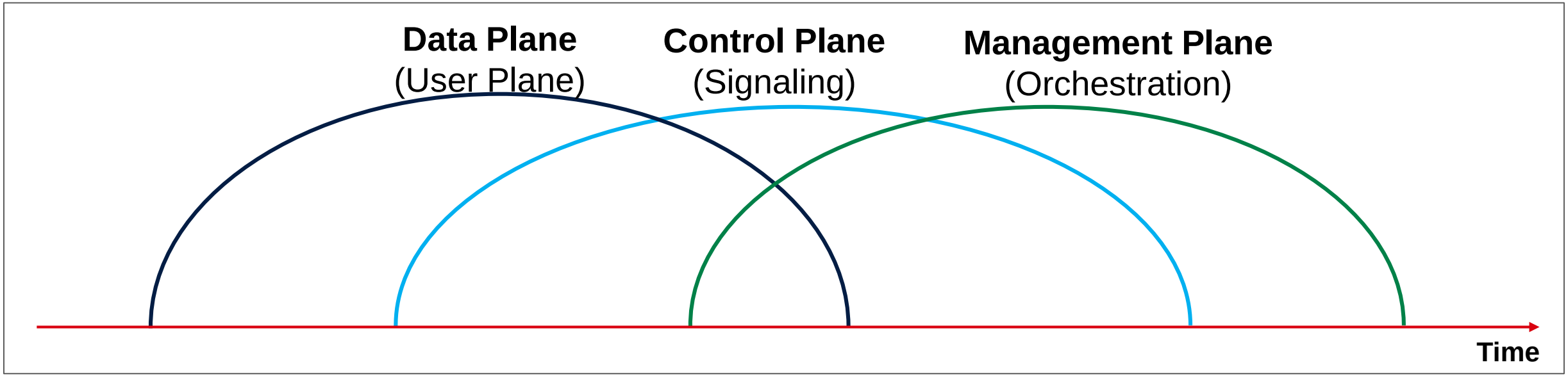
Contract

Packet Header

User Payload

Innovation Cycles of Network Technologies

Every major networking technology, big or small, often has three cycles, and always starts with data plane innovation
Examples: IPv4, IPv6, MPLS, L3VPN, L2VPN, etc



- New applications are coming, requirements are clear, and gaps exist. Now it is exactly the time to start off a new wave of innovations with a new data plane/user plane for wireline data communication networks.
- Every step takes a long time, usually several years. If we start it now, we may achieve something in the year 2030

What Can We Learn from Postal Services?

IP datagram used to be called “letter-gram”, and it enjoys many analogies to postal letters.
Today’s postal services are no longer the postal services of 30 years ago.
Postal services have greatly evolved, but IP hasn’t!

- Customize Delivery Time
- Deliver to Another Address
- Hold at FedEx Location
- Sign for a Package
- Provide Delivery Instructions
- Sign for a Package

Customizable
Programmability

Trackable
Measurement and Telemetry

Assurable
Guaranteed

Billable
New Source of Revenue

Imagine a New IP Packet as a FedEx-like Datagram

FUTUREWEI Technologies

A packet carries a contract between an application and the network.
The network and routers fulfill the contract.

FedEx-like IP Datagram

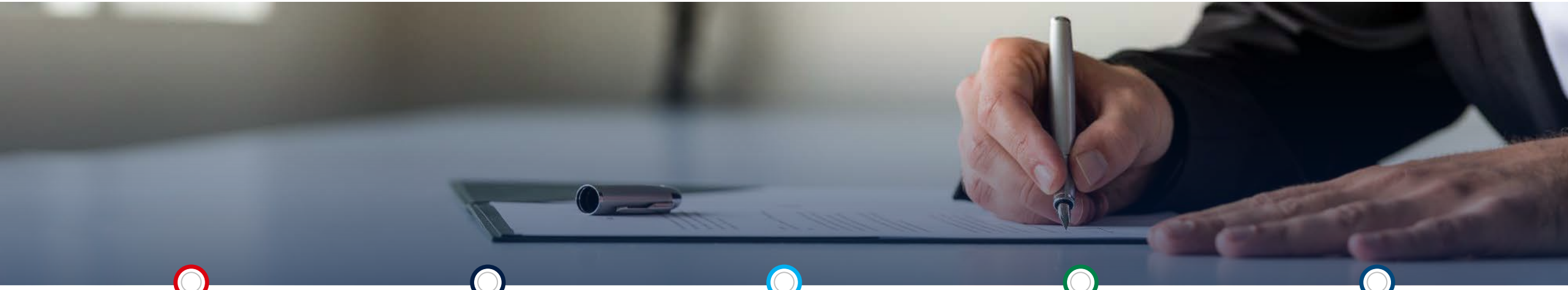
1. The packet arrives in 35ms
2. The packet arrives at 35ms sharp, no sooner no later
3. It requires a throughput of 12 Gbps
4. No packet loss. If lost, you get a compensation.
5. Track it

FedEx Package

1. The package arrives in 1 day
2. The package arrives at 9:00am next day
3. The weight is 12kg
4. No package loss. If lost, you get a refund of $$$.
5. Status track

Ref: Richard Li, et al, A New Framework and Protocol for Future Networking Applications, ACM Sigcomm 2018 NEAT Workshop, Budapest, Hungary, August 2018

What Can a Contract Do in New IP?



High-Precision Communications

- Lossless networking
- Throughout guarantee
- Latency Guarantee (in-time, on-time, coordinated)

User Network Interface (UNI)

In-Band Signaling

High-Precision Telemetry

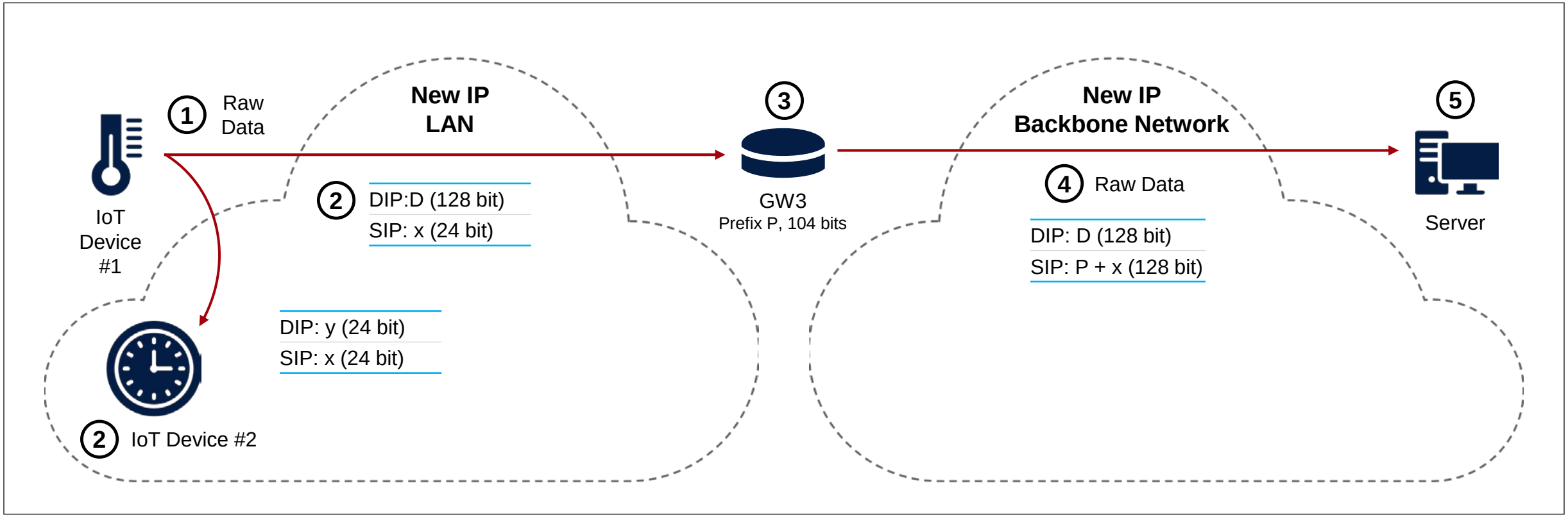
User-Defined Networking

Application-Specific Programmability

Preferred Path Routing (PPR)

E Pluribus Unum:

A Flexible Addressing System (FAS) for ManyNets



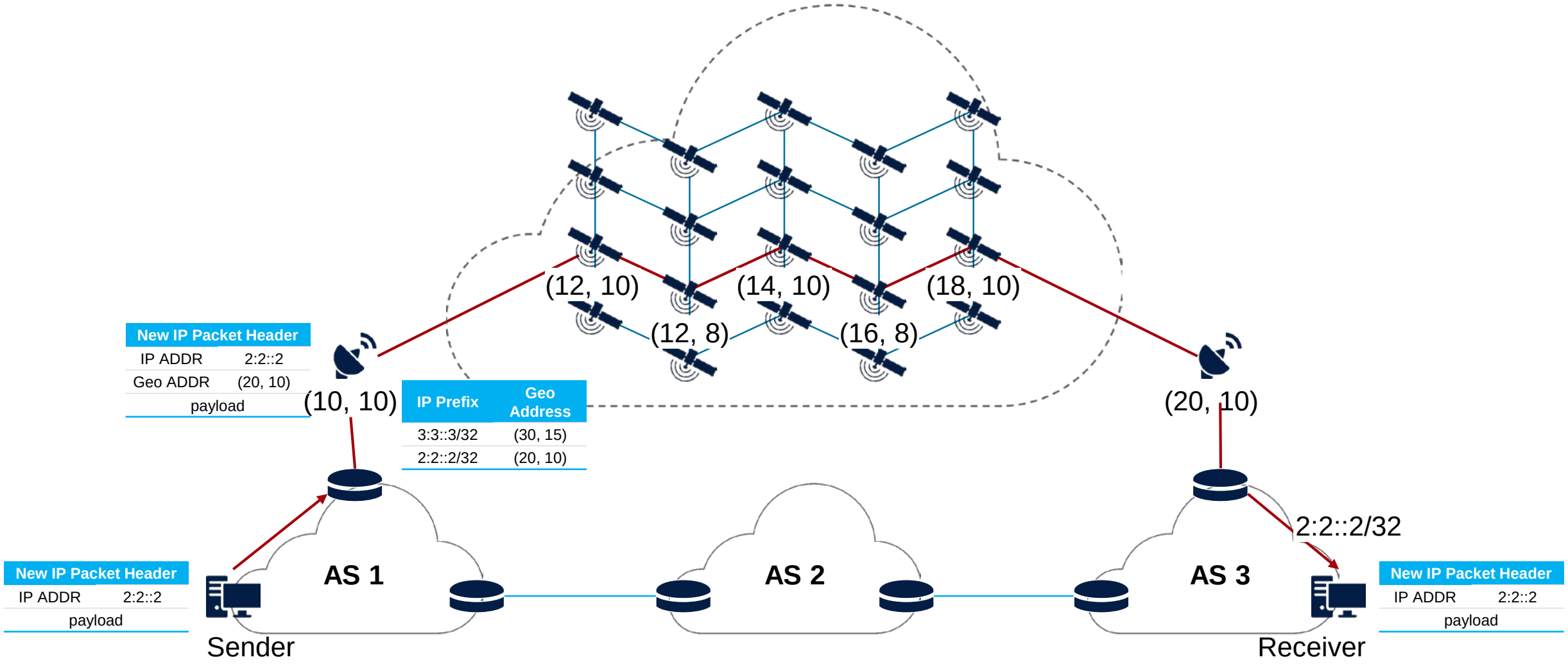
IPv4 host directly talks with IPv6 server, and vice versa

OAM from IPv4 hosts to non-IPv4 nodes

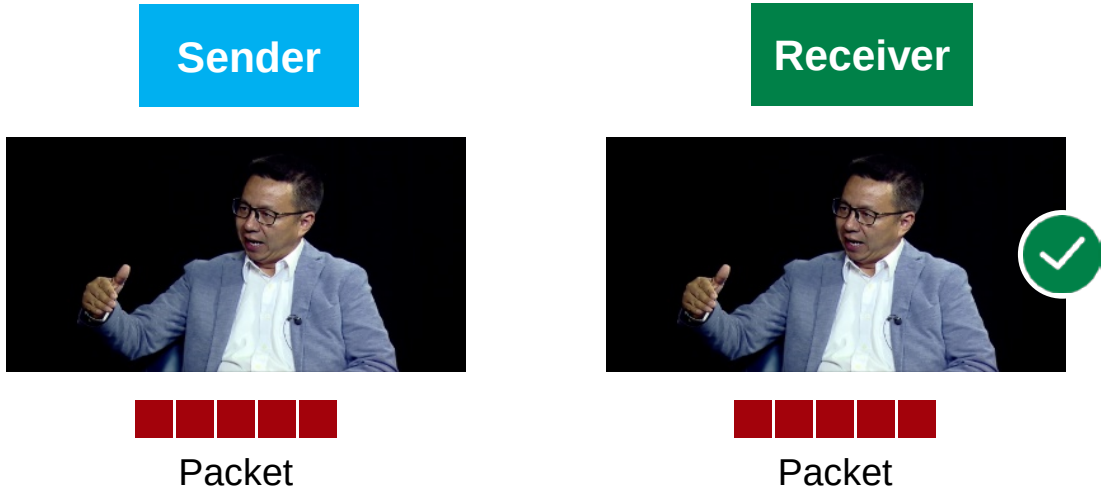
Satellites of different companies talk with each other

Moving Satellites

Topology-based & Geography-based Addressing



Current IP: Quantitative Communications



Syntax

What is received = **What is sent**

Every bit and byte has the same significance to routers/switches

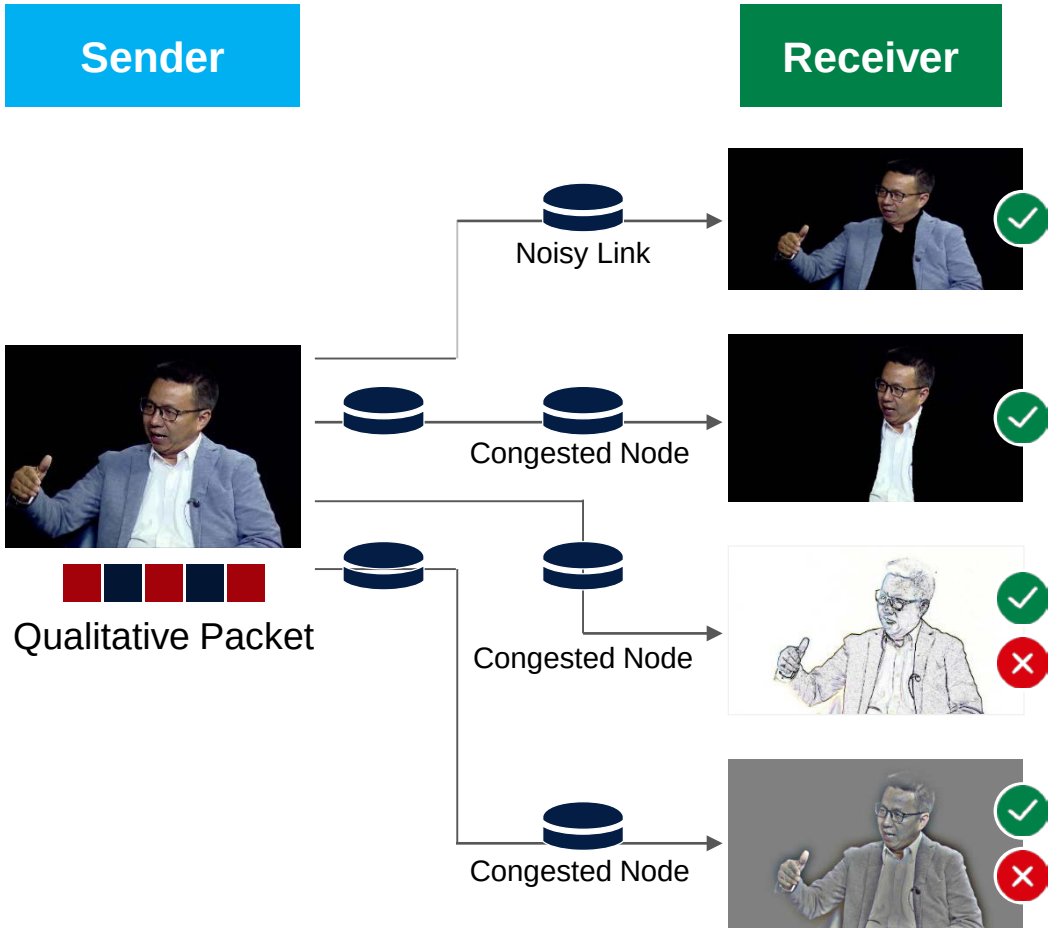
Good for

- File/Document Transfer
- Banking, Shopping

Overkill for some applications

- Holograms
- Disaster Environment

New IP: Qualitative Communications



Ref: A Framework for Qualitative Communications using Big Packet Protocol, ACM Sigcomm 2019 NEAT Workshop, Beijing, August 19, 2019. Available at: https://dl.acm.org/citation.cfm?id=3342201

What is received **Syntax** ≠ **What is sent**

In payload, bits and bytes are not equally significant. Instead, they are differential in their entropies

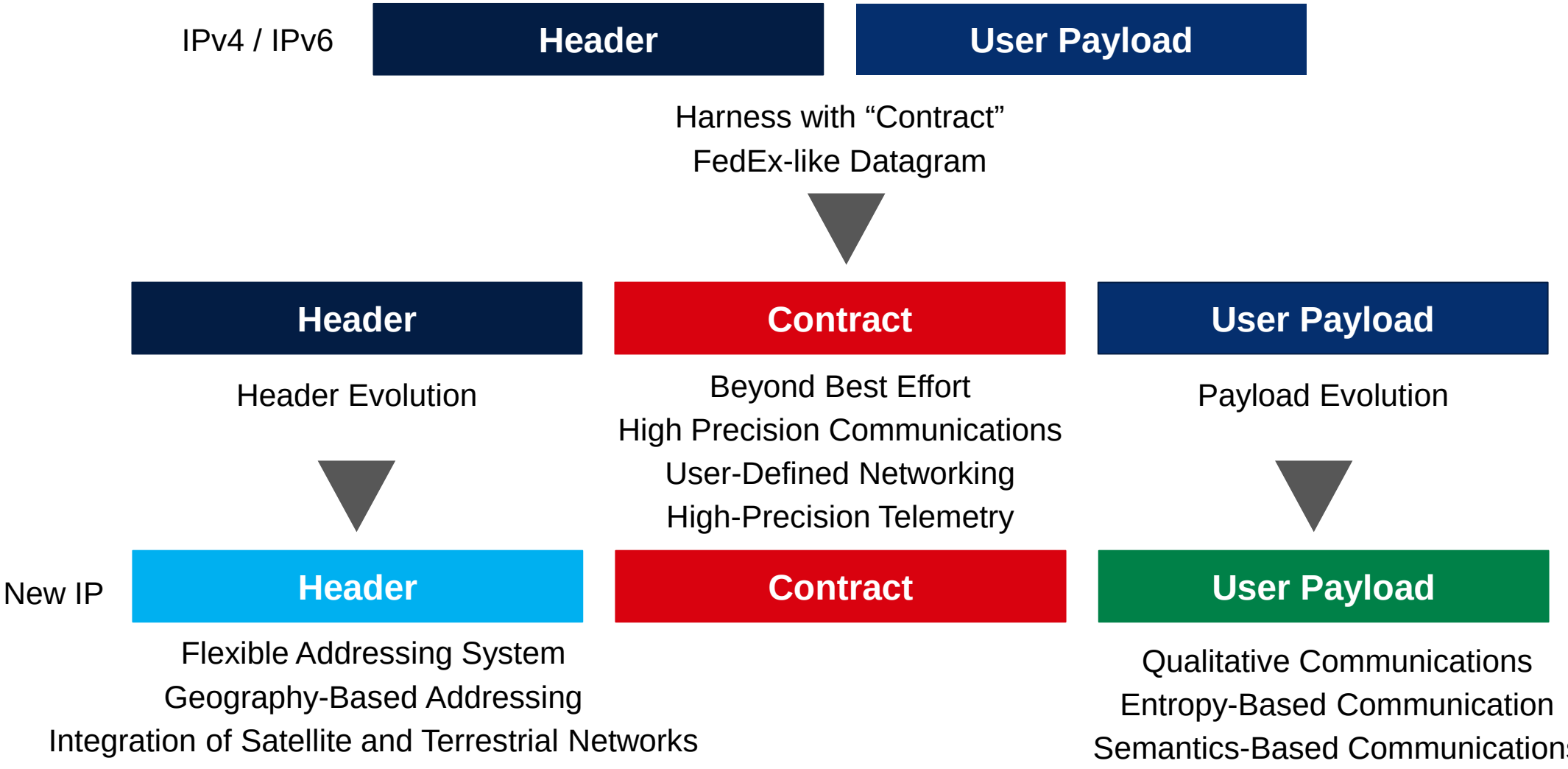
Less significant bits and bytes may be dropped

Partial or degraded, yet useful, packets may be repaired and recovered before being rendered

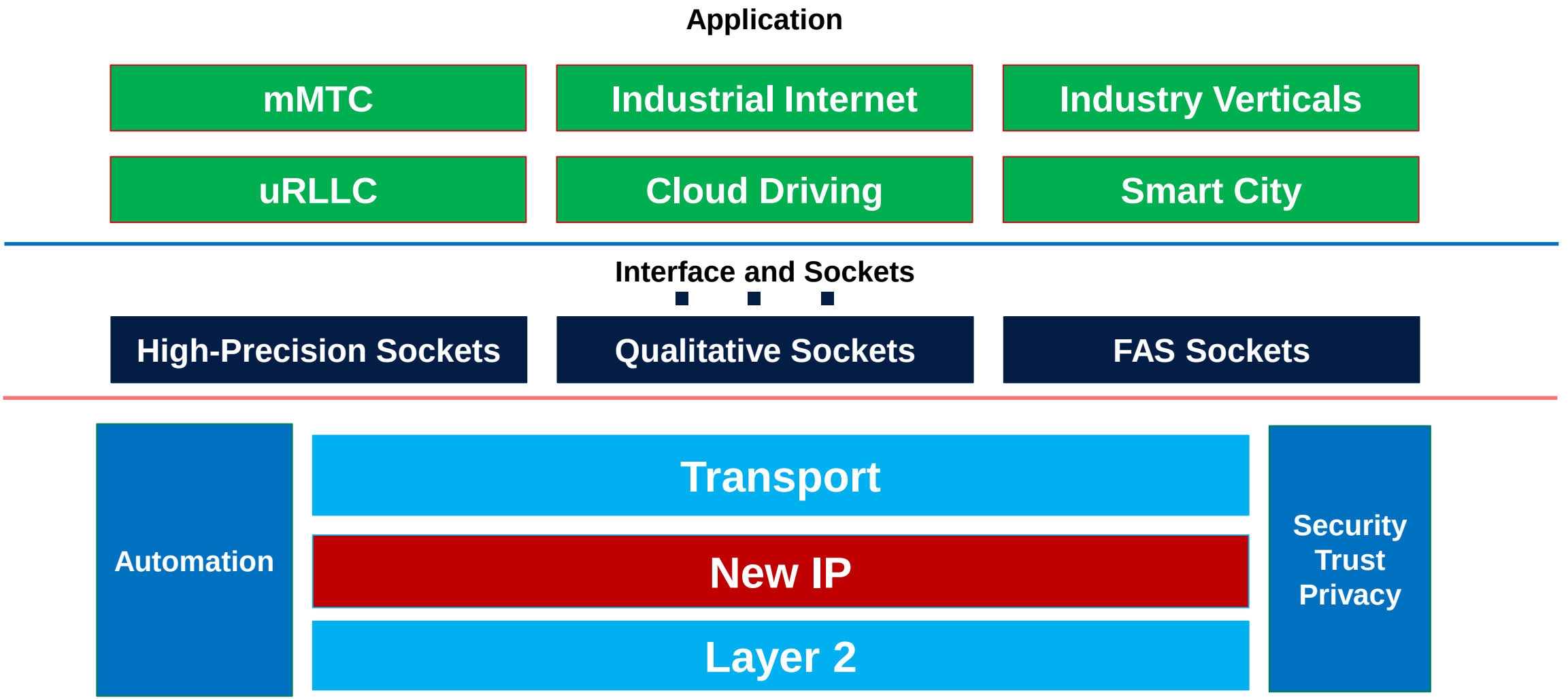
Good for

- Large volume of image-like data
- Holographic type communications
- Media with digital senses
- Disaster Environment

New IP: Evolution Map



New IP for Future Applications



Selected Publications and Talks

Concepts

- Network 2030: A Blueprint of Technology, Applications and Market Drivers Towards the Year 2030 and Beyond, A White Paper of Network 2030, ITU-T, May 2019
- A New Way to Evolve the Internet, A Keynote Speech at IEEE NetSoft 2018, Montreal, Canada, June 2018
- What if we reimagine the Internet?, A Keynote Speech at IEEE ICII 2018, Bellevue, Washington, USA, Oct 2018

Framework and Architecture

- A New Framework and Protocol for Future Networking, ACM Sigcomm 2018 NEAT Workshop, Budapest, August 20, 2018
- A Framework for Qualitative Communications using Big Packet Protocol, ACM Sigcomm 2019 NEAT Workshop, Beijing, August 19, 2019

Market Drivers and Requirements

- Towards a New Internet for the Year 2030 and Beyond, ITU IMT-2020/5G Workshop, Geneva, Switzerland, July 2018
- Network 2030: Market Drivers and Prospects, ITU-T 1st Workshop on Network 2030, New York City, New York, October 2018
- Next Generation Networks: Requirements and Research Directions, ETSI New Internet Forum, the Hague, the Netherlands, October 2018
- The Requirements for the Internet and the Internet Protocol in 2030, ITU-T 3rd Workshop on Network 2030, London, Feb 2019

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- Preferred Path Routing – A Next-Generation Routing Framework beyond Segment Routing, IEEE Globecom 2018, December 2018
- Flow-Level QoS Assurance via In-Band Signaling, 27th IEEE WOCC 2018 , 2018
- Using Big Packet Protocol Framework to Support Low Latency based Large Scale Networks, ICNS 2019, Athens, 2019

Use Cases and Verticals

- A Novel Multi-Factored Replacement Algorithm for In-Network Content Caching, EUCNC 2019, Valencia, Spain, 2019
- Distributed Mechanism for Computation Offloading Task Routing in Mobile Edge Cloud Network, ICNC 2019, Honolulu, USA, 2019
- Enhance Information Derivation by In-Network Semantic Mashup for IoT Applications, EUCNC 2018, Ljubljana, Slovenia, 2018
- Latency Guarantee for Multimedia Streaming Service to Moving Subscriber with 5G Slicing, ISNCC 2018, Rome, Italy, 2018

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