Network 2030 and New IP

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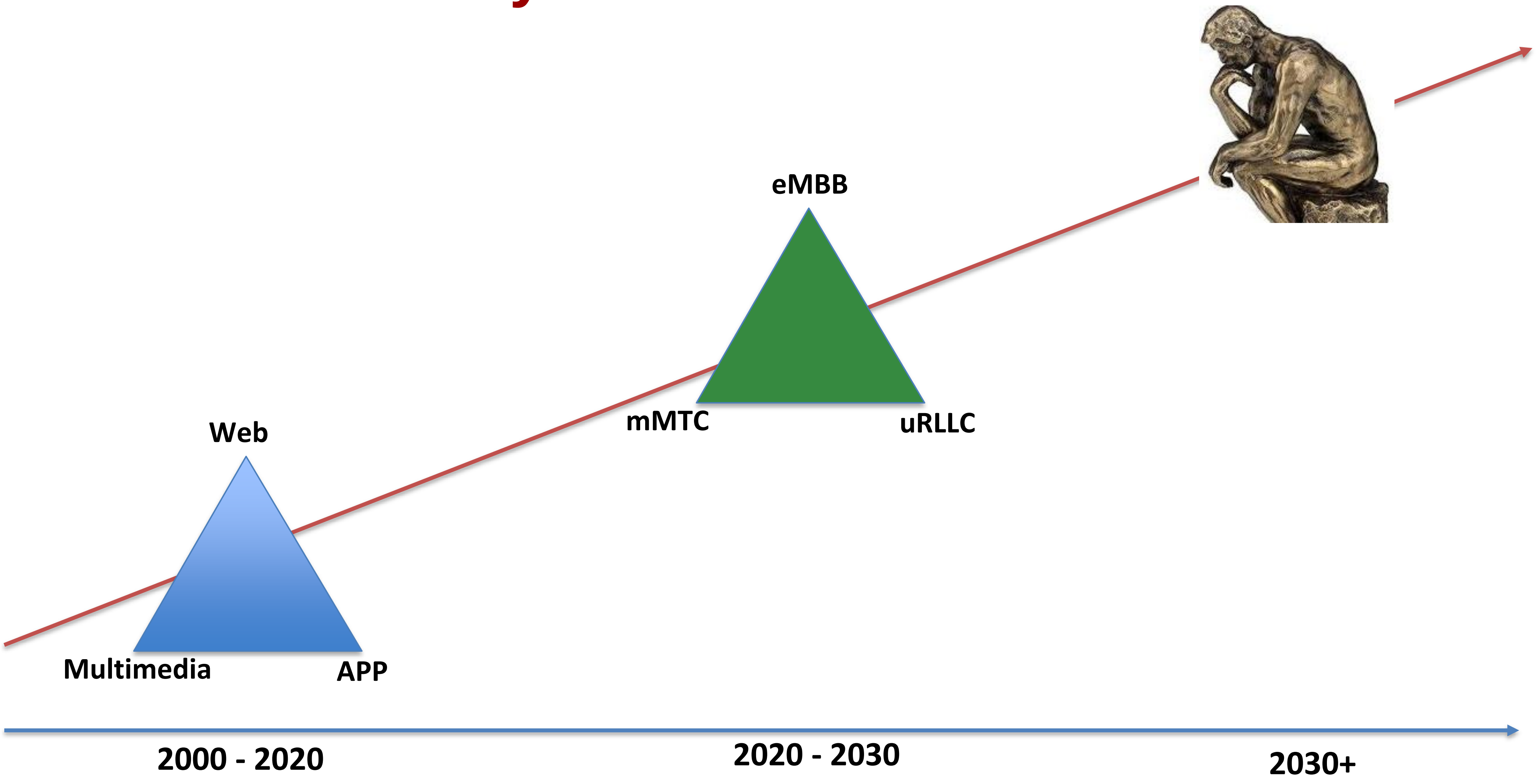
Agenda

- **Network 2030**
  - ITU-T Initiative
  - Driving Forces
- **New IP**
  - Motivation
  - Innovation
- **Summary**

One year ago in 2018, we asked ourselves:
2030 and beyond: What will be?



eMBB

mMTC

uRLLC

Web

Multimedia

APP

2000 - 2020

2020 - 2030

2030+

ITU-T Focus Group on Network 2030

Focus Group on Technologies for Network 2030

Network 2030:
A pointer to the new horizon for the future digital society and networks in the year 2030 and thereafter

Identify future use cases and new requirements

Study 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

2018-2019 Journey of ITU-T Network 2030

Establish

2018.7.16-27

Geneva

1st meeting

2018.10.2-4
NewYork

2nd meeting

2018.12.18-
21

HONGKONG

3rd meeting

Week of 18
February 2019

London

4th meeting

Week of 20
May 2019

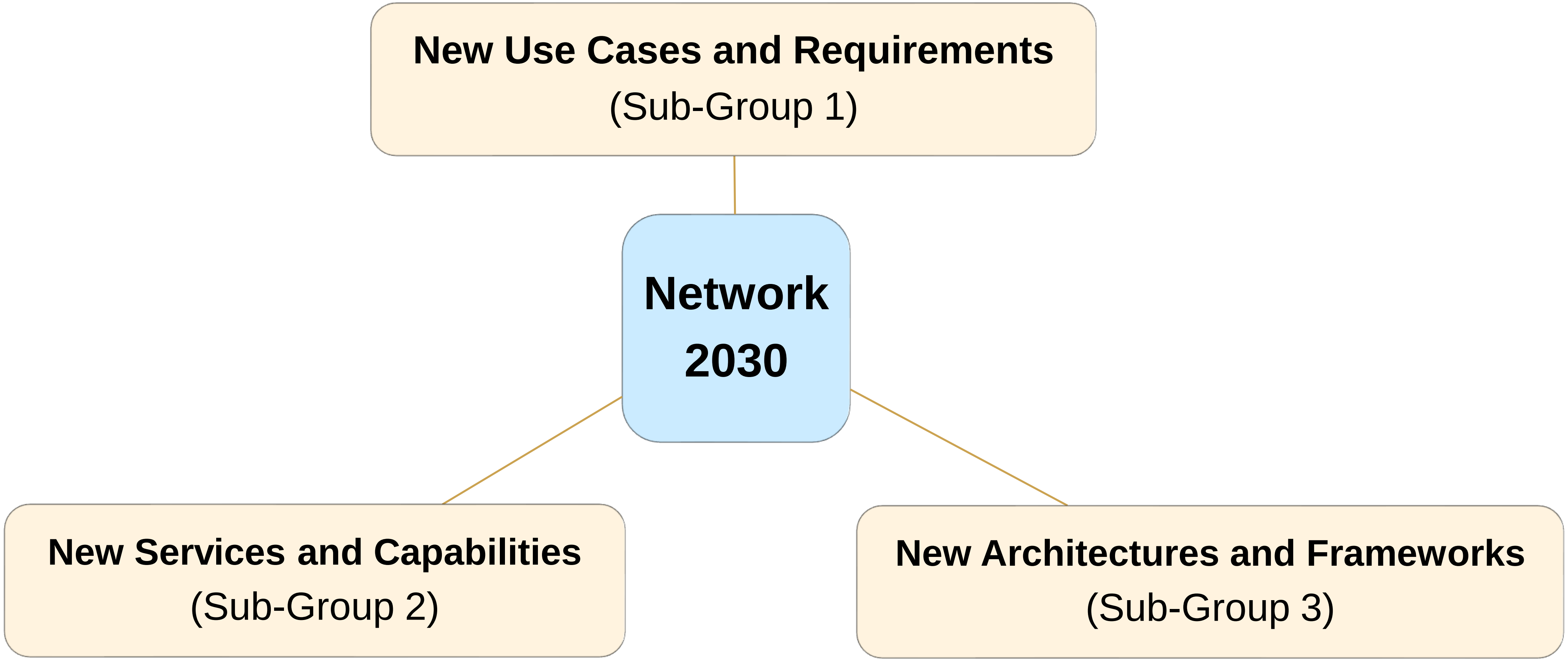
St Petersburg

5th meeting

Oct 2019

Geneva

Focus and Deliverables



New Use Cases and Requirements
(Sub-Group 1)

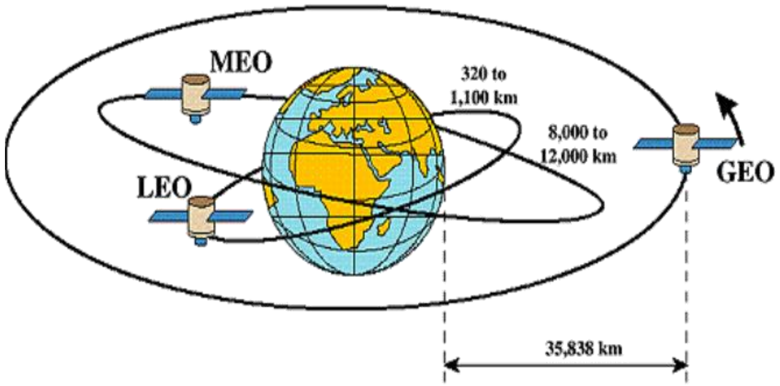
Network 2030

New Services and Capabilities
(Sub-Group 2)

New Architectures and Frameworks
(Sub-Group 3)

Space Internet

Beaming internet with satellites on earth orbit



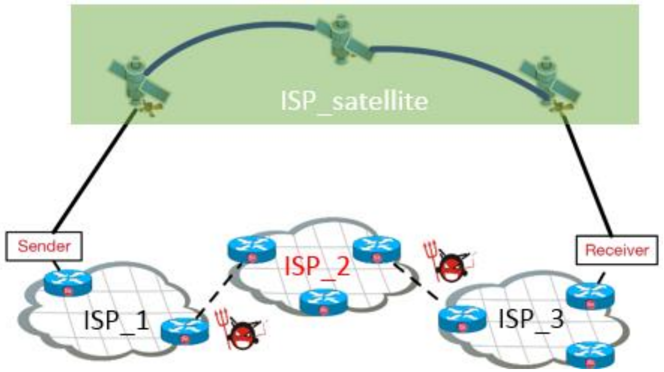
Geosynchronous Earth Orbit
GEO: 35,838 km

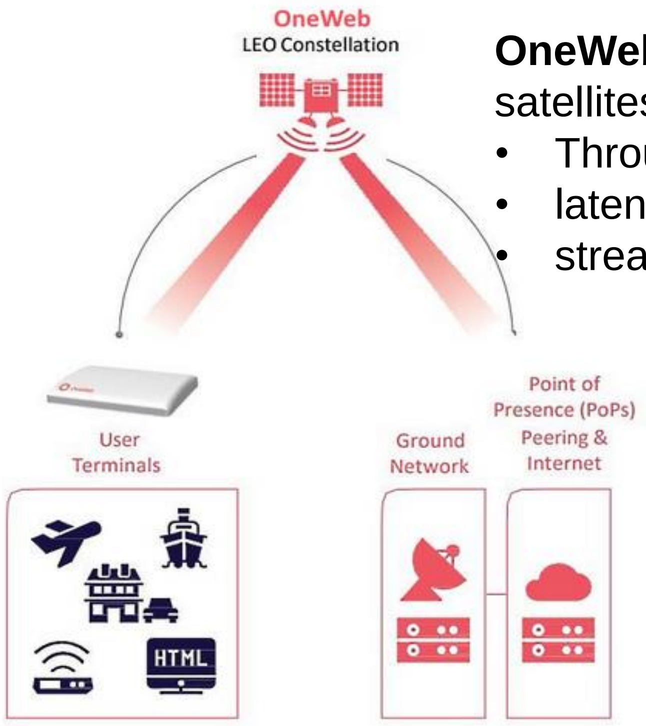
Medium Earth Orbit
MEO: ~10,000 km

Low Earth Orbit
LEO: ~1000 km

Near future use

- Internet for Arctic
- Emergency relief
- High-speed aviation and navigation broadband
- Cross-border secure transmission





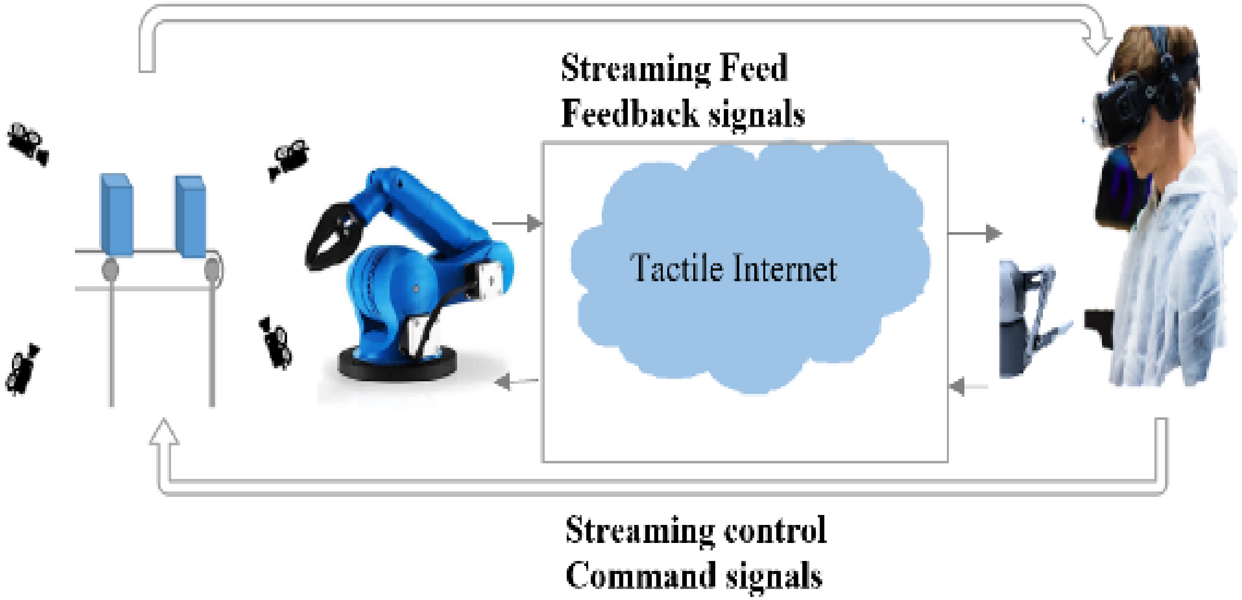
OneWeb launched 6 airbus satellites to LEO in 2019.02.

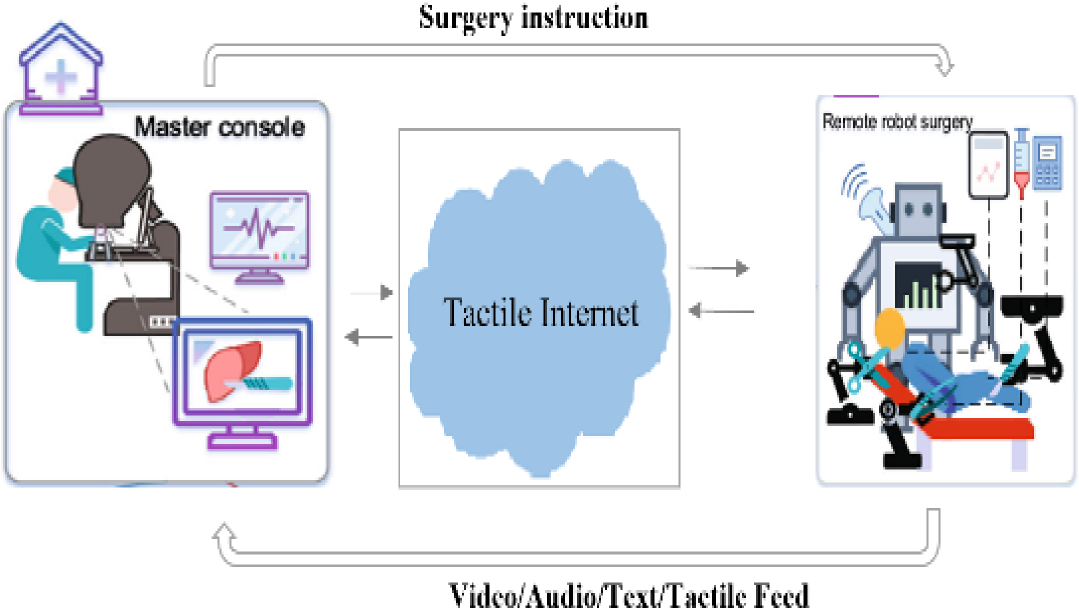
- Throughput 400Mbps
- latency 40ms
- stream HD video at 1080p

Company	Support	No. of Satellites
Starlink	SpaceX (Elon Musk)	4K by 2019, then 12K
Oneweb	Softbank	650 by 2019
Boeing	Apple (spec)	2956, 1350 in 6 yrs
O3Nb	Virgin group, SES	400
CASIC	China	300 (54 trial)

Tactile Internet

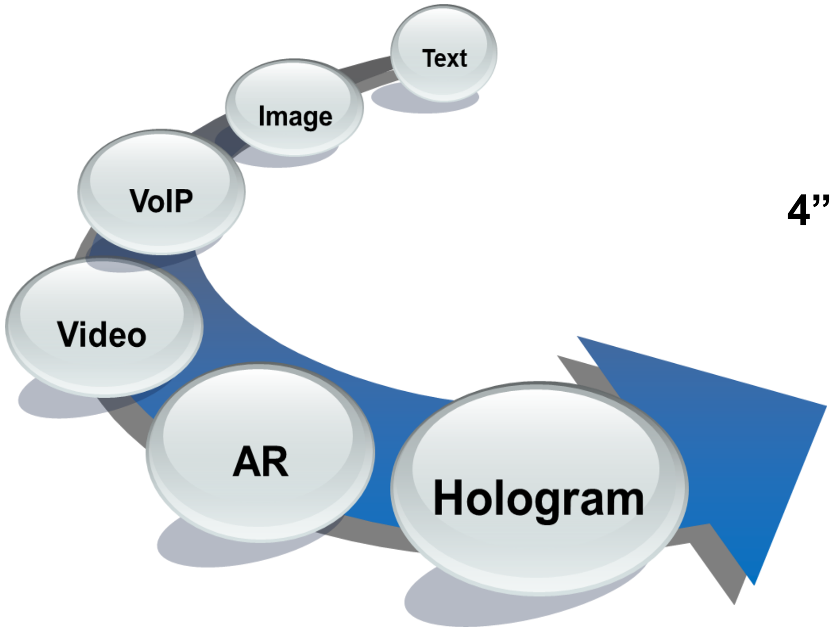
Enabling tactile and haptic sensations to human-to-machine interaction

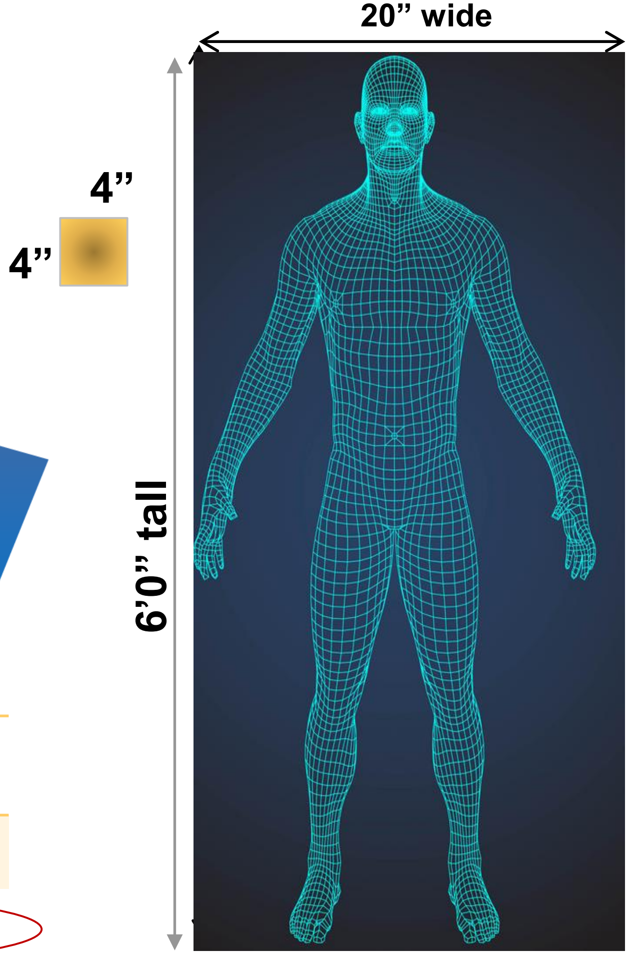




- **Ultra-low latency**: Sub-millisecond to 5 milliseconds.
- **Ultra-low loss**: Loss of packets is almost intolerable
- **Ultra-high bandwidth**: From 360-degree video to holograms. VR feed: 5 Gbps; Holograms: Tbps
- **Stringent synchronization**: Different human-brain reaction times to different sensory 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.

Holograms and Holographic Type Communications





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

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

(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)

Throughput goes up

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

Holographic Twin: Latency falls down

4K/8K HD — **15 ms~35 ms** → delay → **VR/AR** — **5 ms~7 ms** → delay → **Hologram** — **Sub ms~7ms**

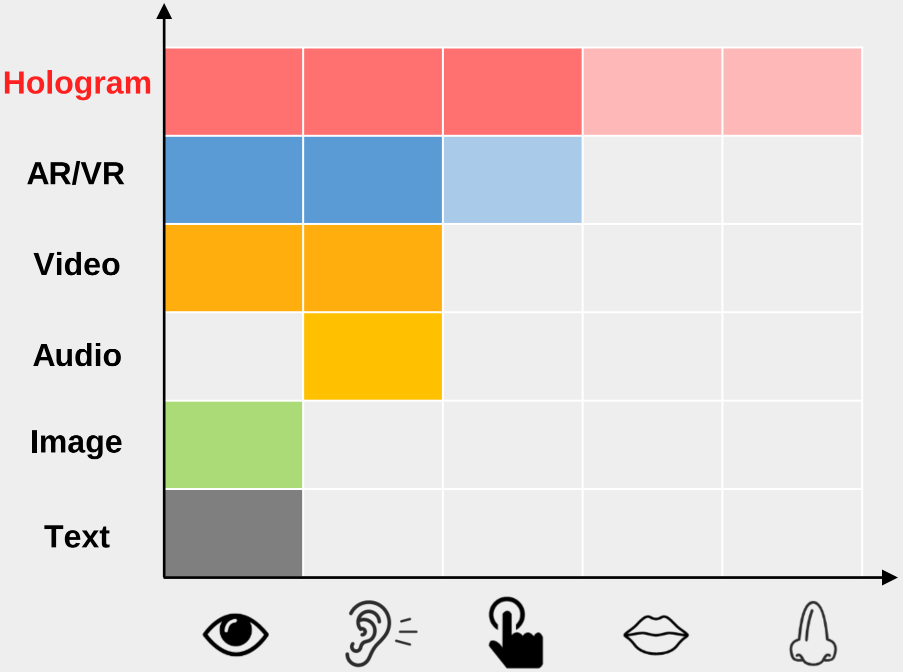
Synchronization of parallel streams

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

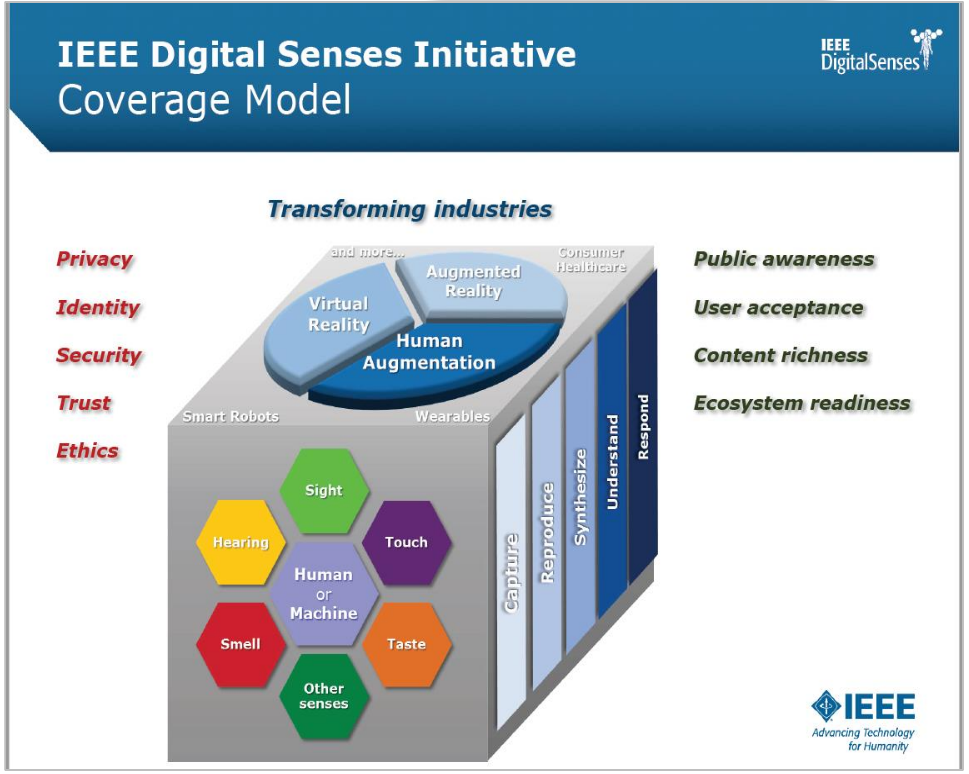
Holographic Type Communications: Attach Digital Senses to Holograms

1T/s	1ms
1G/s	17ms
100M/s	33ms
64k/s	50ms

Media Evolution



	👁	👂	☝	👄	👃
Hologram	🟥	🟥	🟥	🟥	🟥
AR/VR	🟦	🟦	🟦		
Video	🟧	🟧			
Audio		🟨			
Image	🟩				
Text	⬛				



IEEE Digital Senses Initiative
Coverage Model

Transforming industries

Privacy
Identity
Security
Trust
Ethics

Public awareness
User acceptance
Content richness
Ecosystem readiness

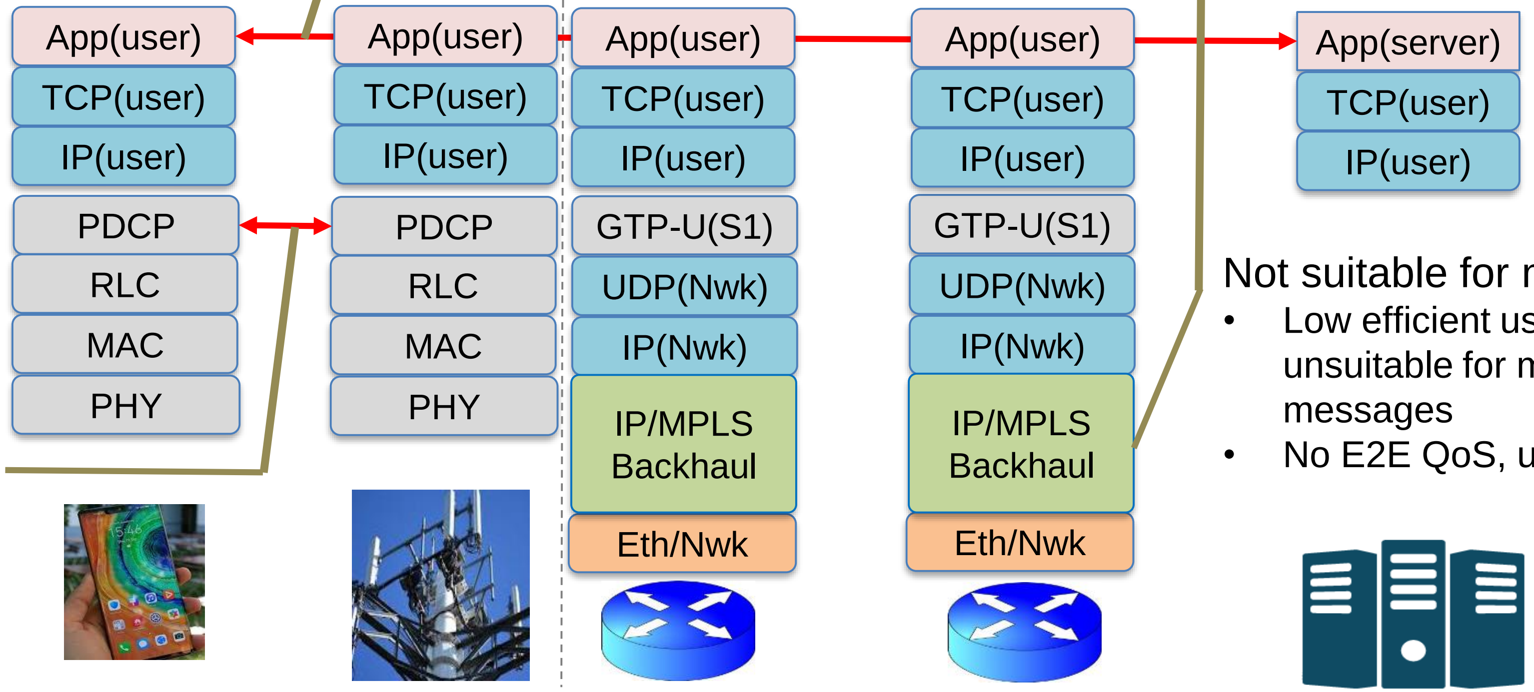
End-to-End Precise Requirements

RAN has evolved, but IP/MPLS networks stay the same

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

Inefficient use of protocols

- Tunnels over tunnels
- Duplicate header fields



Inefficient retransmission

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

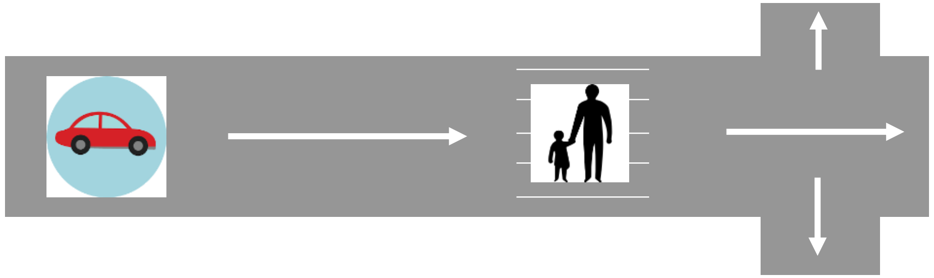
Not suitable for mMTC and uRLLC

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

Cellular network

Fixed, IP based wireline network

Case Study: Tele-Driving in U of California, Berkeley

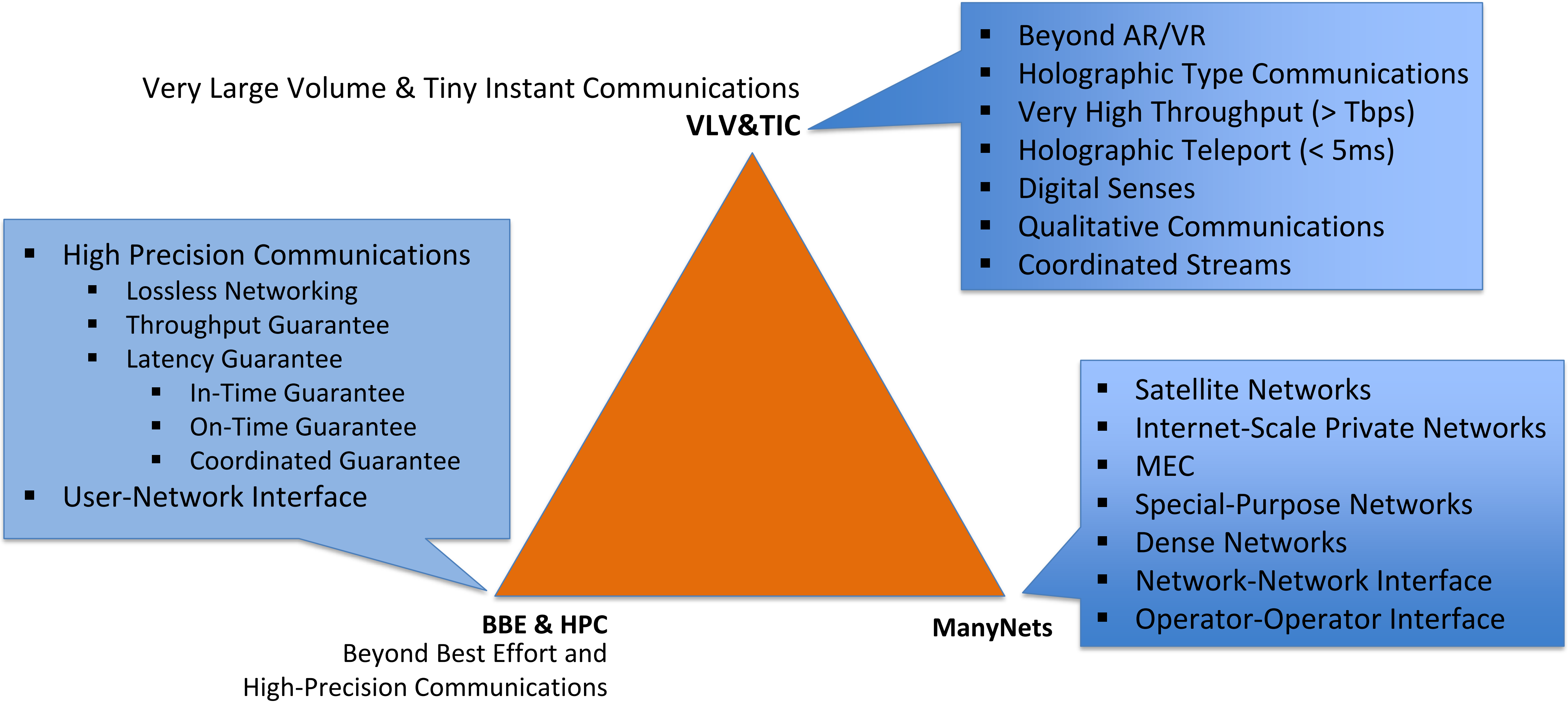


Sensory Image Capture: 40ms
Framing + Encoding: 120 ms
Decoding + Display: 100ms
RTT between Colombia to San Francisco: 200 – 400ms

Total: 460 – 660 ms

Extrapolation:
1) 5 km/hour = 1.4m/sec. Crash-Avoidance distance = 1.4m/sec x 660ms = 0.92m
2) 30 km/hour = 8.4m/sec. Crash-Avoidance distance = 8.4m/sec x 660ms = 5.54m
3) 60 km/hour = 16.8m/sec. Crash-Avoidance distance = 16.8m/sec x 660ms = 11.08m

All ITU FG Network 2030 has done in the past year leads to:



Very Large Volume & Tiny Instant Communications
VLV&TIC

- Beyond AR/VR
- Holographic Type Communications
- Very High Throughput (> Tbps)
- Holographic Teleport (< 5ms)
- Digital Senses
- Qualitative Communications
- Coordinated Streams

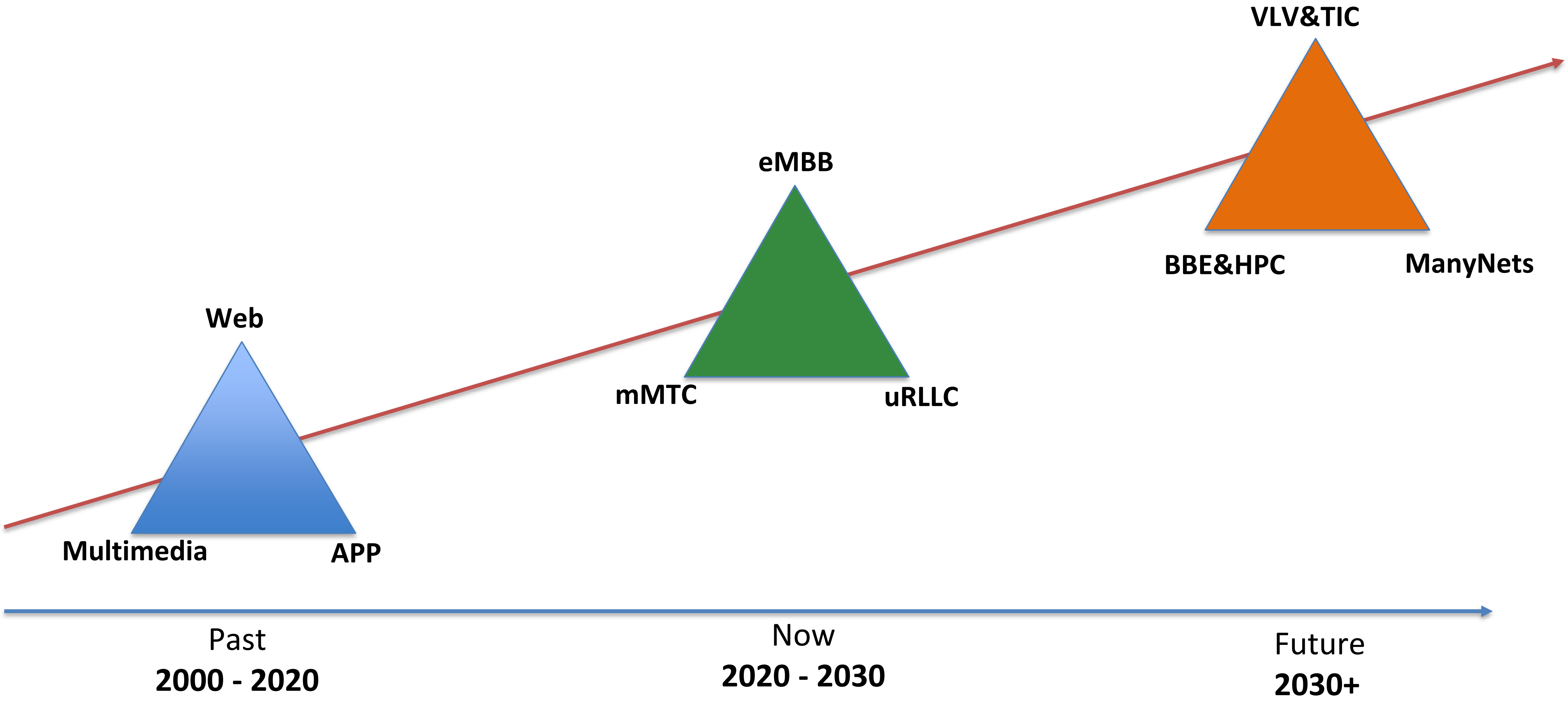
- High Precision Communications
    - Lossless Networking
    - Throughput Guarantee
    - Latency Guarantee
        - In-Time Guarantee
        - On-Time Guarantee
        - Coordinated Guarantee
- User-Network Interface

BBE & HPC
Beyond Best Effort and
High-Precision Communications

ManyNets

- Satellite Networks
- Internet-Scale Private Networks
- MEC
- Special-Purpose Networks
- Dense Networks
- Network-Network Interface
- Operator-Operator Interface

Now we can see something in the future

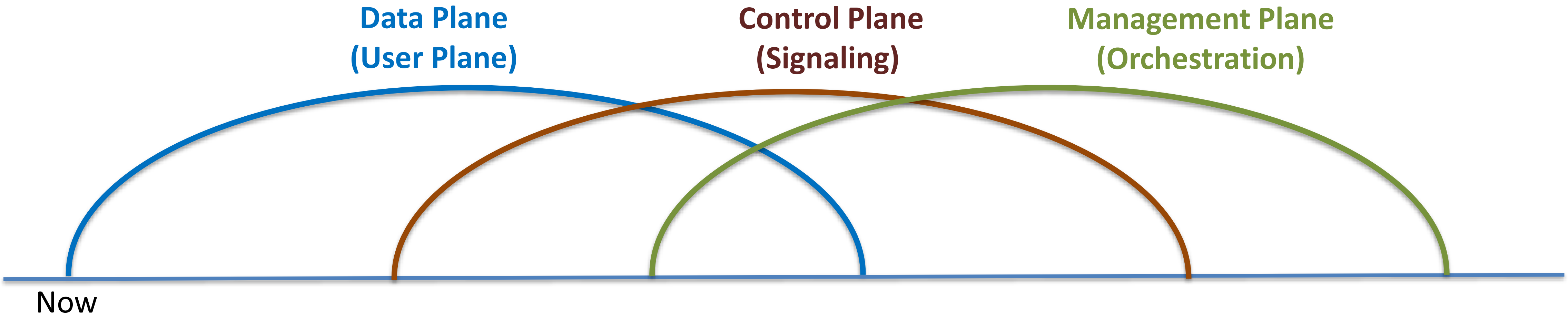


New IP: an Evolved IP Way to Solve Network 2030

- Why?
- Contract
- Packet Header Evolution
- User Payload Evolution

Evolution Cycles of Network Technologies

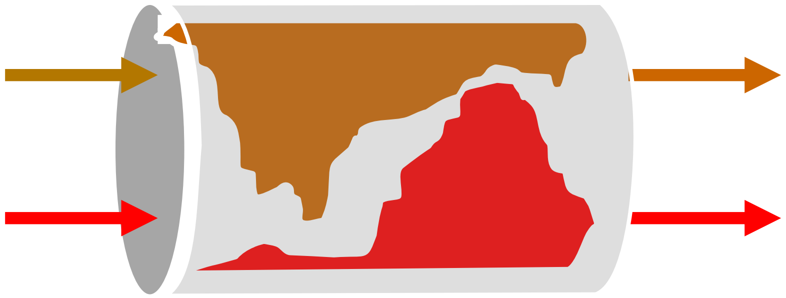
Every major networking technology, big or small, often has three cycles, and always starts with data plane innovation
Examples: IPv4, IPv6, MPLS, L3VPN, L2VPN, etc



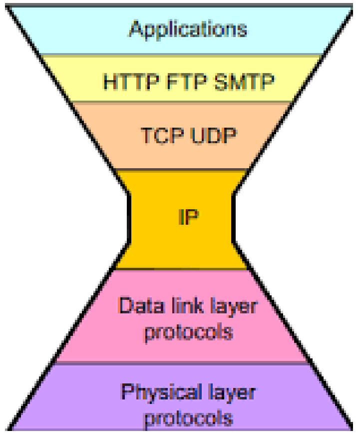
- **New applications are coming, requirements are clear, and gaps exist. Now it is exactly the time to start off a new wave of innovations with a new data plane/user plane for wireline data communication networks.**
- **Every step takes a long time, to be estimated 10 years. If we start it now, we may have something in 2030**

A Brief Analysis on IP

Statistical Multiplexing



One Size Fits All



Packet switching: 2019-1961 = 58 years
TCP/IP: 2019-1974 = 45 years

Capabilities and Services:

- ❖ Best Effort
- ❖ DiffServ
- ❖ Traffic Engineering
  - Explicit Path
  - Bandwidth Guarantee
  - Fast Re-Route

- One common network layer to connect everything globally
- Fairness (Neutrality)
- Maximize network utilization: Matching traffic demand to available capacity
- End-to-end principle to keep the network free of session/application state

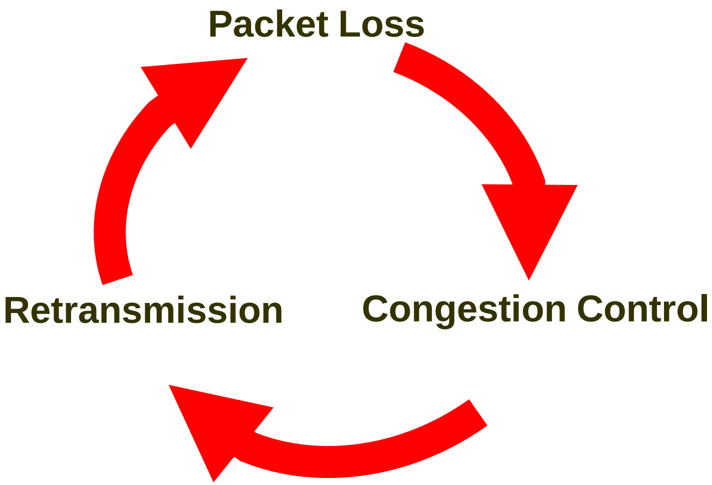
- ✓ Innovation Above, Below, and Alongside
- ✓ But, Limited Innovation “Inside” the ’Net
- ✓ But, the inside of the network does need to change
- ✓ We Are Desperate to Innovate Inside

Jennifer Rexford, ACM Sigcomm 2018 Keynote Speech

Throughput, Latency and Packet Loss

- Throughput **should be** linearly proportional to bandwidth: $T = c_1 \times BW$
- Latency **should be** linearly proportional to physical distance: $L = c_2 \times D$
- Packet loss **should be** an inverse function of buffer sizes: $L = c_3 / B$

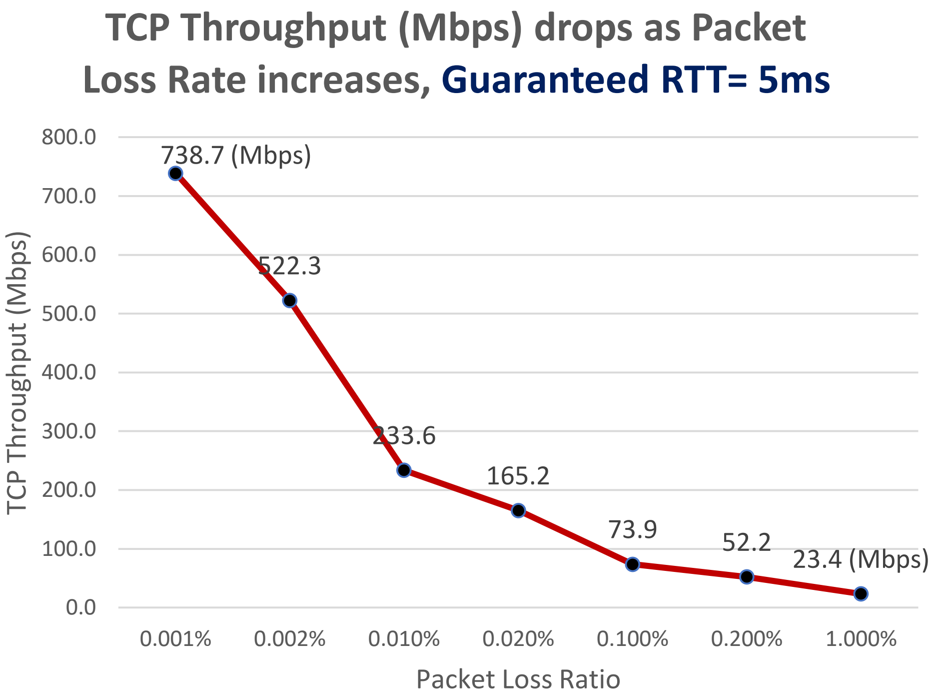
But, they are not!

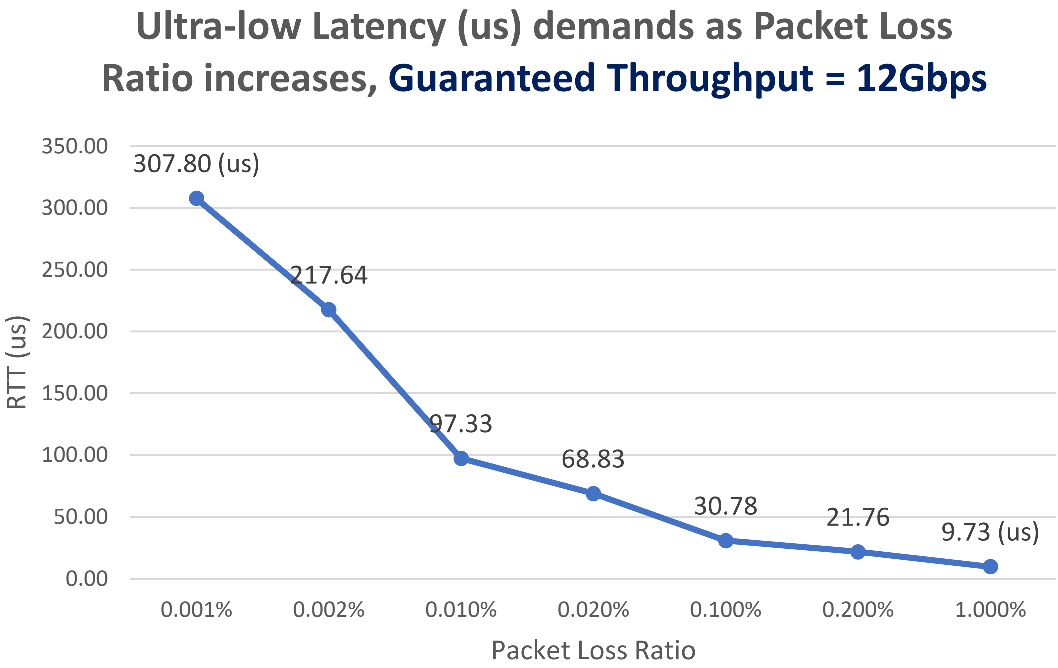


Cerf-Kahn-Mathis Equation

$$T \leq \min\left(BW, \frac{\text{WindowSize}}{\text{RTT}}, \frac{\text{MSS}}{\text{RTT}} \times \frac{C}{\sqrt{\rho}}\right)$$

Packet Loss Impacts on Throughput and Latency





Assuming:

- MSS (Max Segment Size = 1460 Byte)
- Throughput Upbound = (MSS/RTT)*(C/sqrt(Loss)) [C=1] (based on the Mathis et.al. formula)

What Can We Learn from Postal Services?

IP datagram used to be called “lettergram” in its early history, and it enjoys many analogies with postal service. But today’s postal service is no longer your grandparents’ postal service.

896893915002455

Fri 12/07 Delivered: Waipahu, HI Wed 12/12

Signed for by: SSTORM

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

Billable

Pay as you go

Trackable

Measurement and Telemetry

Customizable

Programmability

Assurable

guaranteed

Imagine a new IP packet as a FedEx-like Datagram


IP Header | Contract | User Payload

- ☐ **A packet carries a contract from an application to the network**
- ☐ **The network and routers process the contract**

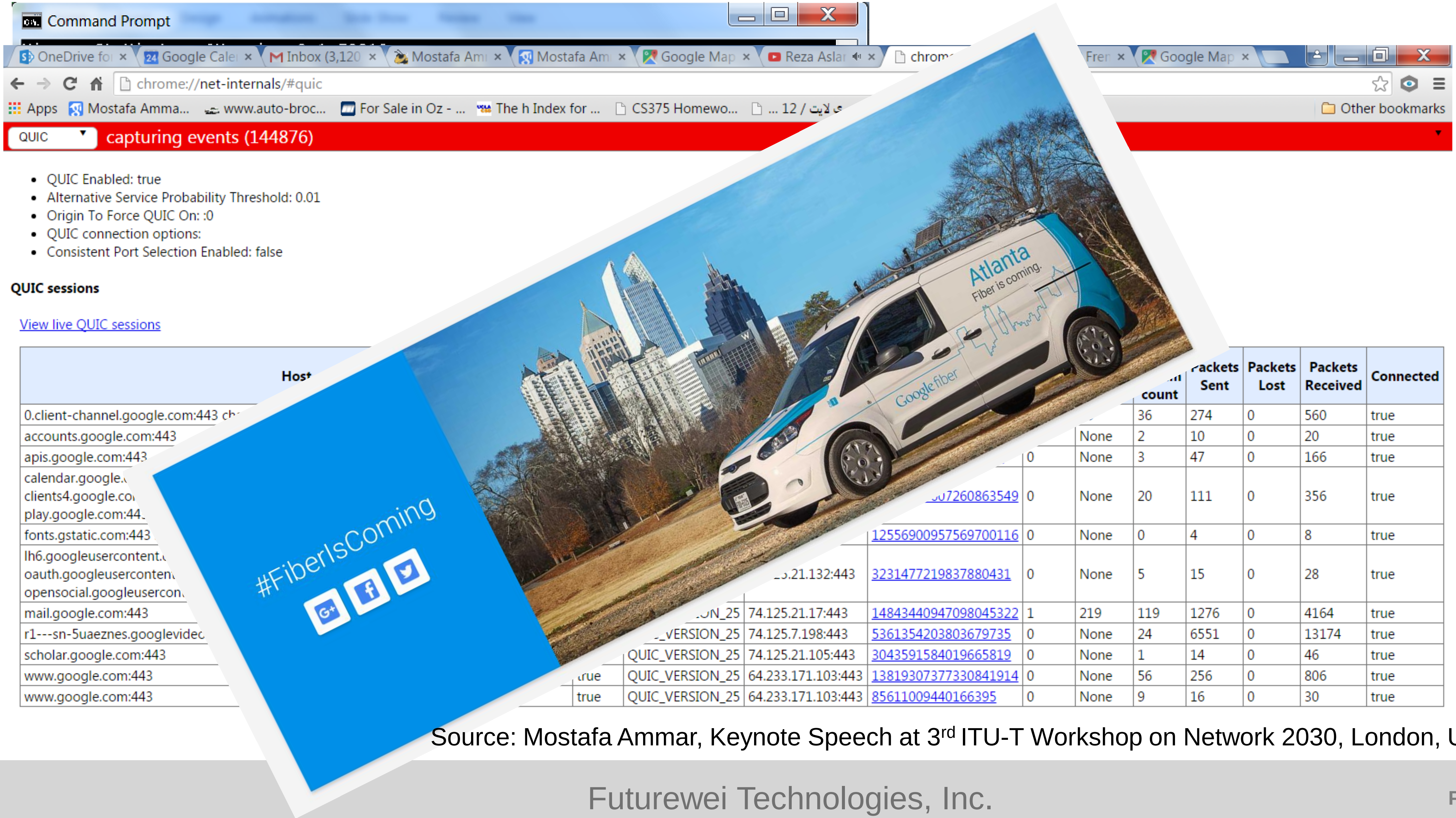
New IP	**FedEx**
1) The packet arrives in 35ms	1) The package arrives in 1 day
2) The packet arrives at 35ms later sharp	2) The packages arrives at 9:00AM next day
3) I require a throughput of 12Gbps	3) The weight is 12kg
4) No packet loss. If lost, you get a compensation	4) No package loss. If lost, you get a refund of $$$
5) Track it	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?

- High Precision Communications
  - Lossless networking
  - Throughput guarantee
  - Latency Guarantee (in-time, on-time, coordinated)
- User Network Interface (UNI)
- In-Band Signaling
- In-Band Telemetry
- User-Defined Networking
  - Application-Specific Programmability
  - Preferred Path Routing (PPR)

Is Google using the Internet?



- QUIC Enabled: true
- Alternative Service Probability Threshold: 0.01
- Origin To Force QUIC On: :0
- QUIC connection options:
- Consistent Port Selection Enabled: false

QUIC sessions

View live QUIC sessions

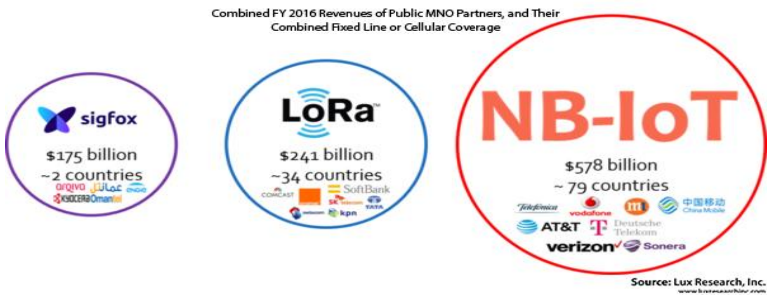
Host							count	Packets Sent	Packets Lost	Packets Received	Connected
0.client-channel.google.com:443 ch							36	274	0	560	true
accounts.google.com:443						None	2	10	0	20	true
apis.google.com:443					0	None	3	47	0	166	true
calendar.google. clients4.google.co play.google.com:44				07260863549	0	None	20	111	0	356	true
fonts.gstatic.com:443				12556900957569700116	0	None	0	4	0	8	true
lh6.googleusercontent. oauth.googleuserconten opensocial.googleusercon			.21.132:443	3231477219837880431	0	None	5	15	0	28	true
mail.google.com:443		ON_25	74.125.21.17:443	14843440947098045322	1	219	119	1276	0	4164	true
r1---sn-5uaeznes.googlevidec		_VERSION_25	74.125.7.198:443	5361354203803679735	0	None	24	6551	0	13174	true
scholar.google.com:443		QUIC_VERSION_25	74.125.21.105:443	3043591584019665819	0	None	1	14	0	46	true
www.google.com:443	true	QUIC_VERSION_25	64.233.171.103:443	13819307377330841914	0	None	56	256	0	806	true
www.google.com:443	true	QUIC_VERSION_25	64.233.171.103:443	85611009440166395	0	None	9	16	0	30	true

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

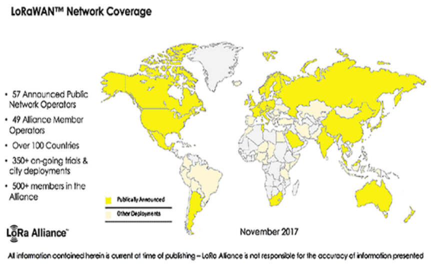
ManyNets: Embracing Diversity, Variety, and Economy

Non-IP Networks

(Growing market segment)



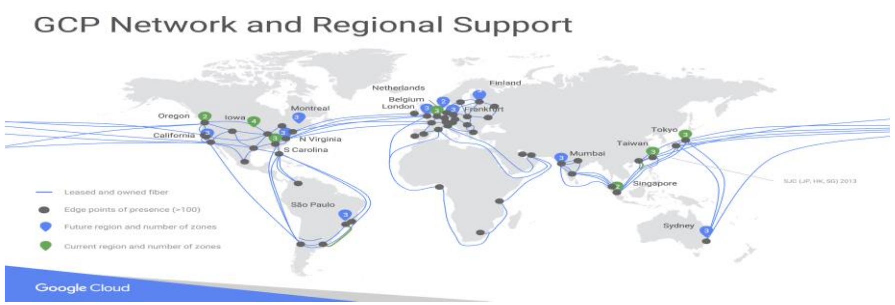
Spread Networks

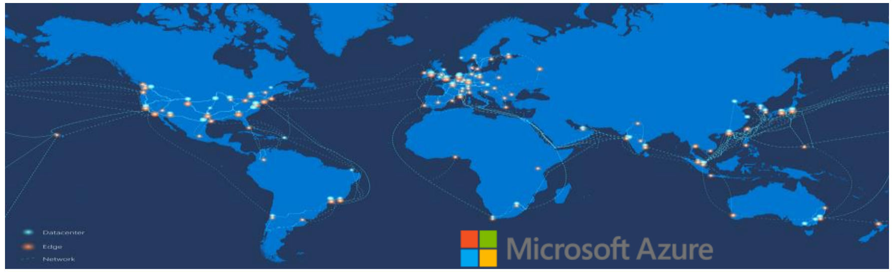


FirstNet®

Private Global Backbones

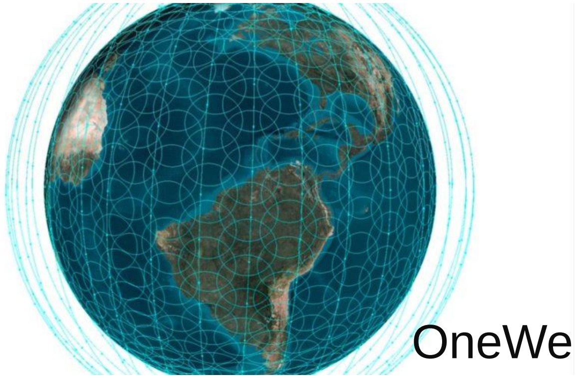
(Death of Internet Transit)



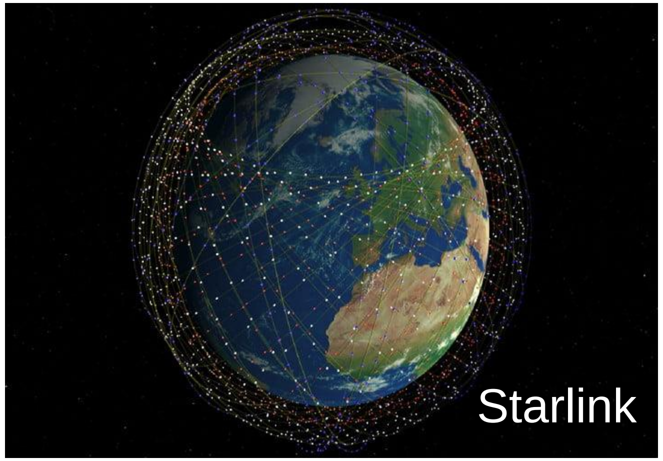


Emerging Satellite Constellations

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



OneWeb



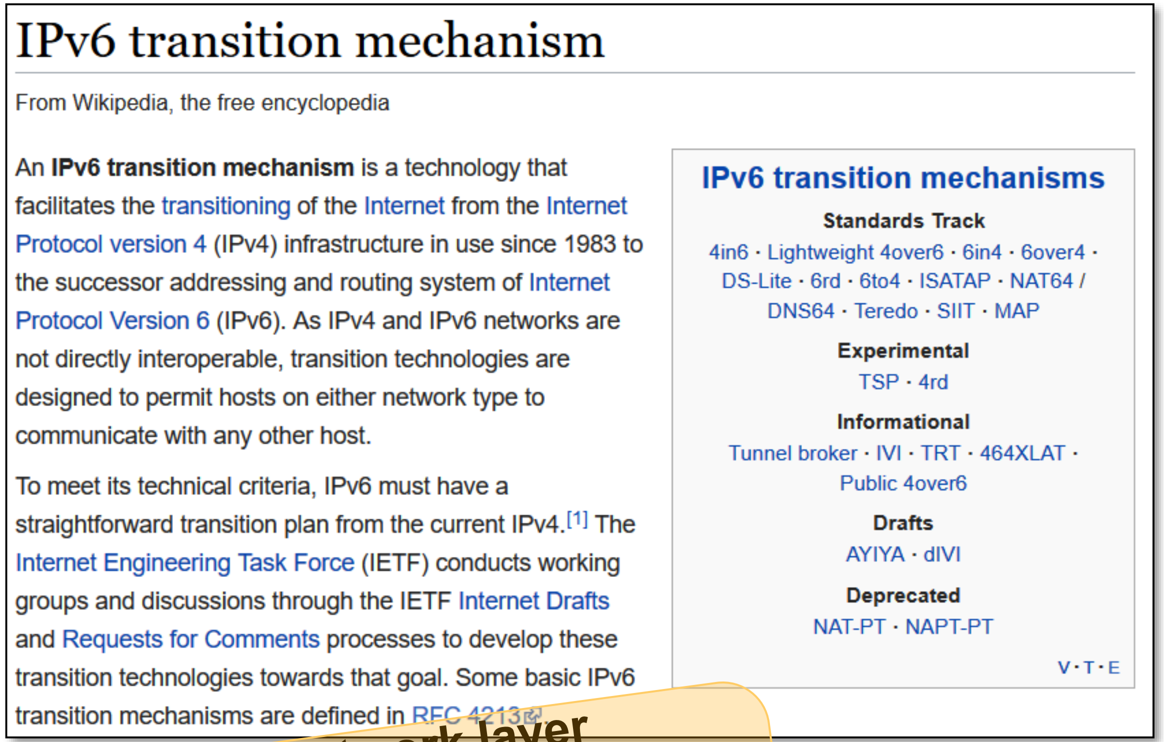
Starlink

Challenges in IPv6 adoption for ManyNets

- Are you happy with the following facts?
  - It has been 24 years without universal adoption since the first IPv6 RFC in 1995 (RFC 1883)
  - More than 10 RFC ways of migration from IPv4 to IPv6, making the Internet to be de-facto heterogeneous.

- Fixed 128 bit addressing helped address space, but
  - Overkill for low power devices
  - Ambiguity in the use of its internal structure

- The growing heterogeneity makes it
  - more expensive for deployments
  - less interoperability
  - solve problems like manageability, security, mobility
  - again and again inefficiently



IPv6 transition mechanism

From Wikipedia, the free encyclopedia

An **IPv6 transition mechanism** is a technology that facilitates the transitioning of the Internet from the Internet Protocol version 4 (IPv4) infrastructure in use since 1983 to the successor addressing and routing system of Internet Protocol Version 6 (IPv6). As IPv4 and IPv6 networks are not directly interoperable, transition technologies are designed to permit hosts on either network type to communicate with any other host.

To meet its technical criteria, IPv6 must have a straightforward transition plan from the current IPv4.[1] The Internet Engineering Task Force (IETF) conducts working groups and discussions through the IETF Internet Drafts and Requests for Comments processes to develop these transition technologies towards that goal. Some basic IPv6 transition mechanisms are defined in RFC 4213

IPv6 transition mechanisms

Standards Track
4in6 · Lightweight 4over6 · 6in4 · 6over4 · DS-Lite · 6rd · 6to4 · ISATAP · NAT64 / DNS64 · Teredo · SIIT · MAP

Experimental
TSP · 4rd

Informational
Tunnel broker · IVI · TRT · 464XLAT · Public 4over6

Drafts
AYIYA · dIVI

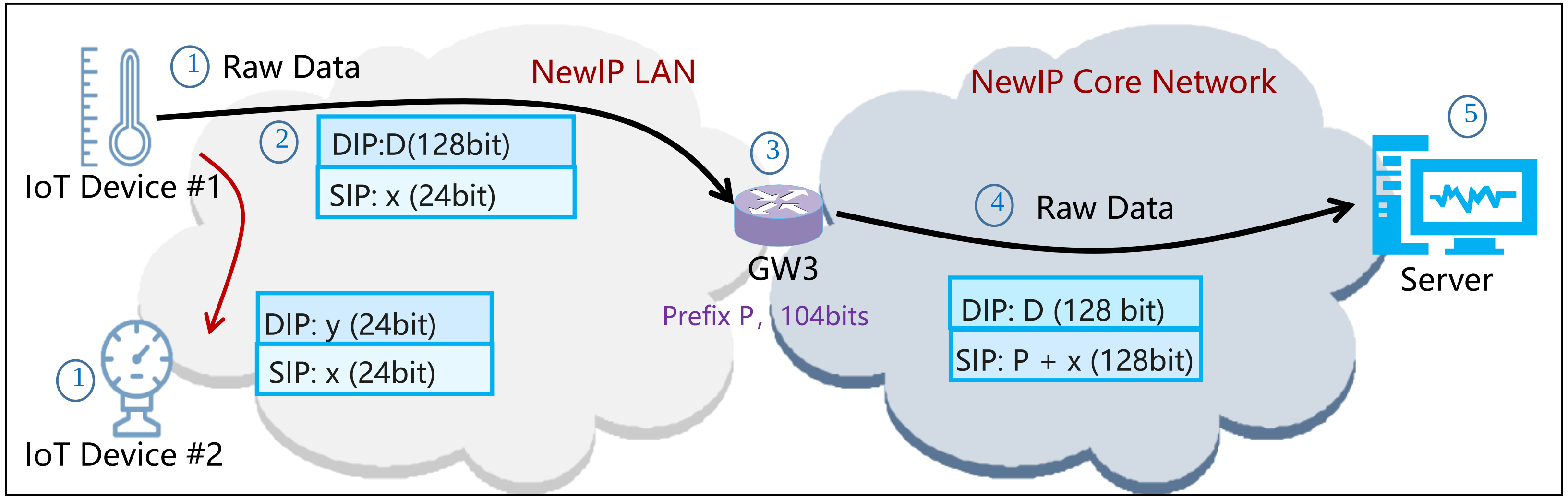
Deprecated
NAT-PT · NAPT-PT

V · T · E

Can we make a new network layer protocol based on IP which addresses these growing ManyNets market segments, perhaps with backward compatibility?

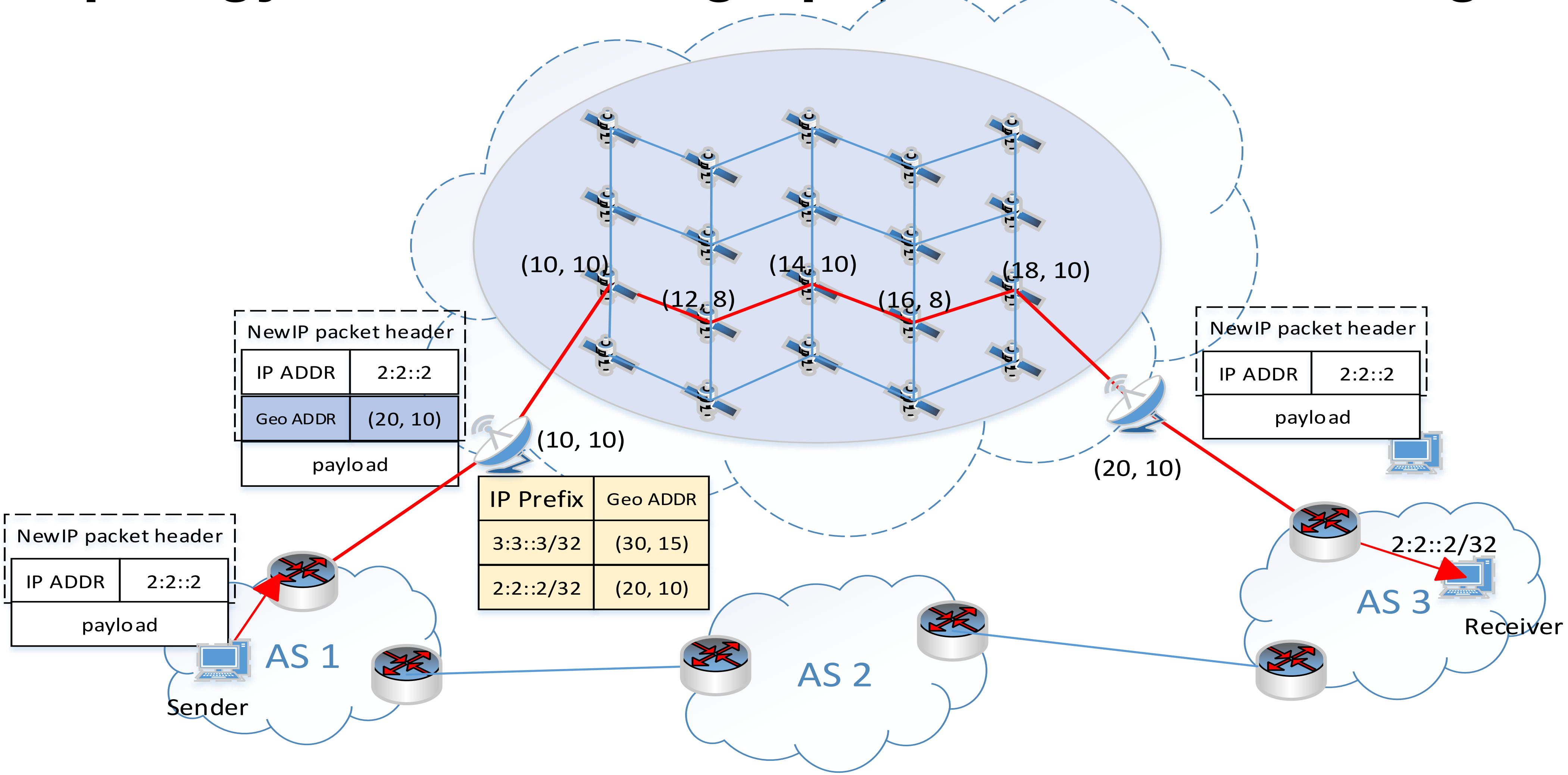
E Pluribus Unum:

Can we design a Flexible Addressing System (FAS)?



- OAM easily goes from one net to another net
- States and State Machines are made unnecessary on borders

Moving Nodes:
Topology-based & Geography-based Addressing



NewIP packet header

IP ADDR	2:2::2
Geo ADDR	(20, 10)
payload	

NewIP packet header

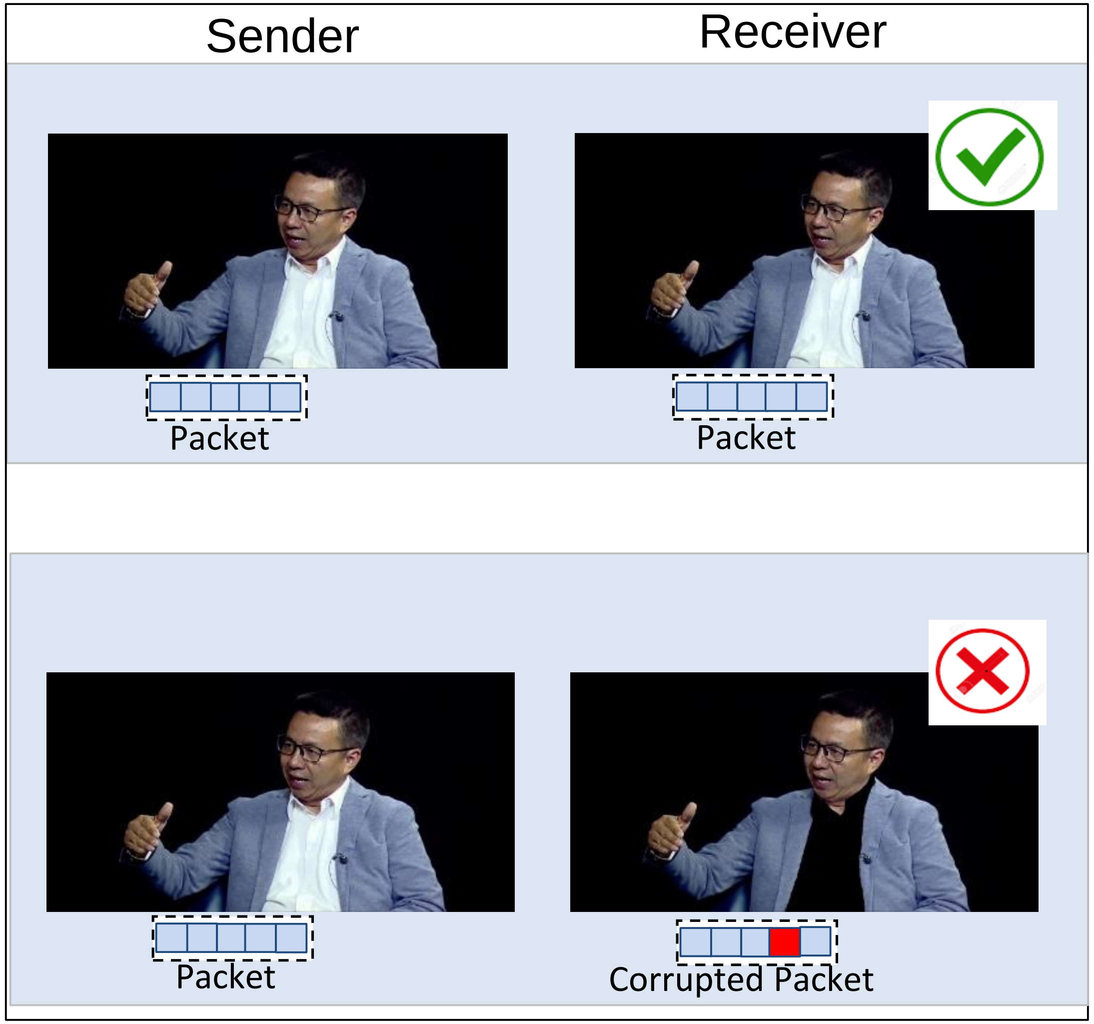
IP ADDR	2:2::2
payload	

NewIP packet header

IP ADDR	2:2::2
payload	

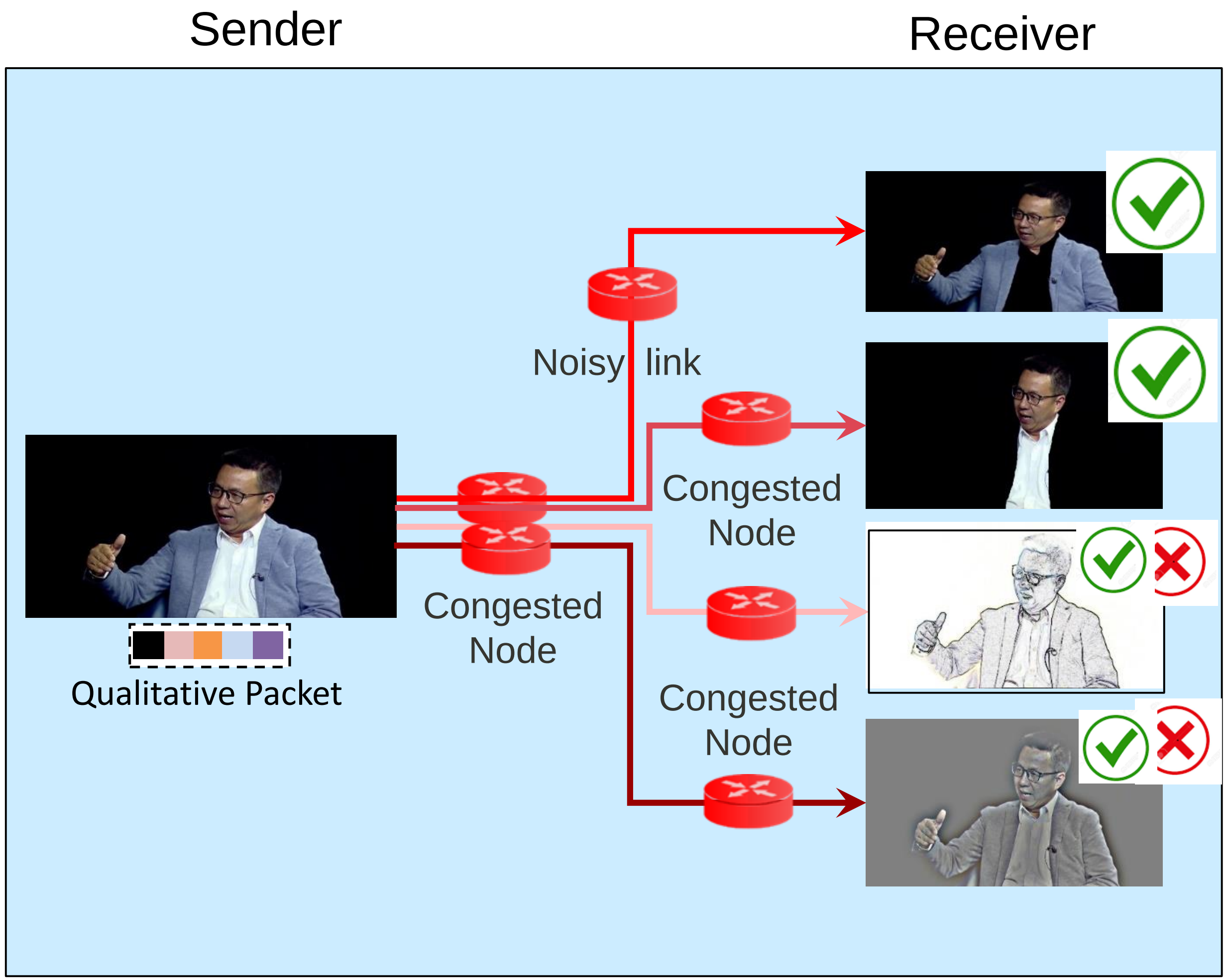
IP Prefix	Geo ADDR
3:3::3/32	(30, 15)
2:2::2/32	(20, 10)

Current IP: Quantitative Communications



- 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

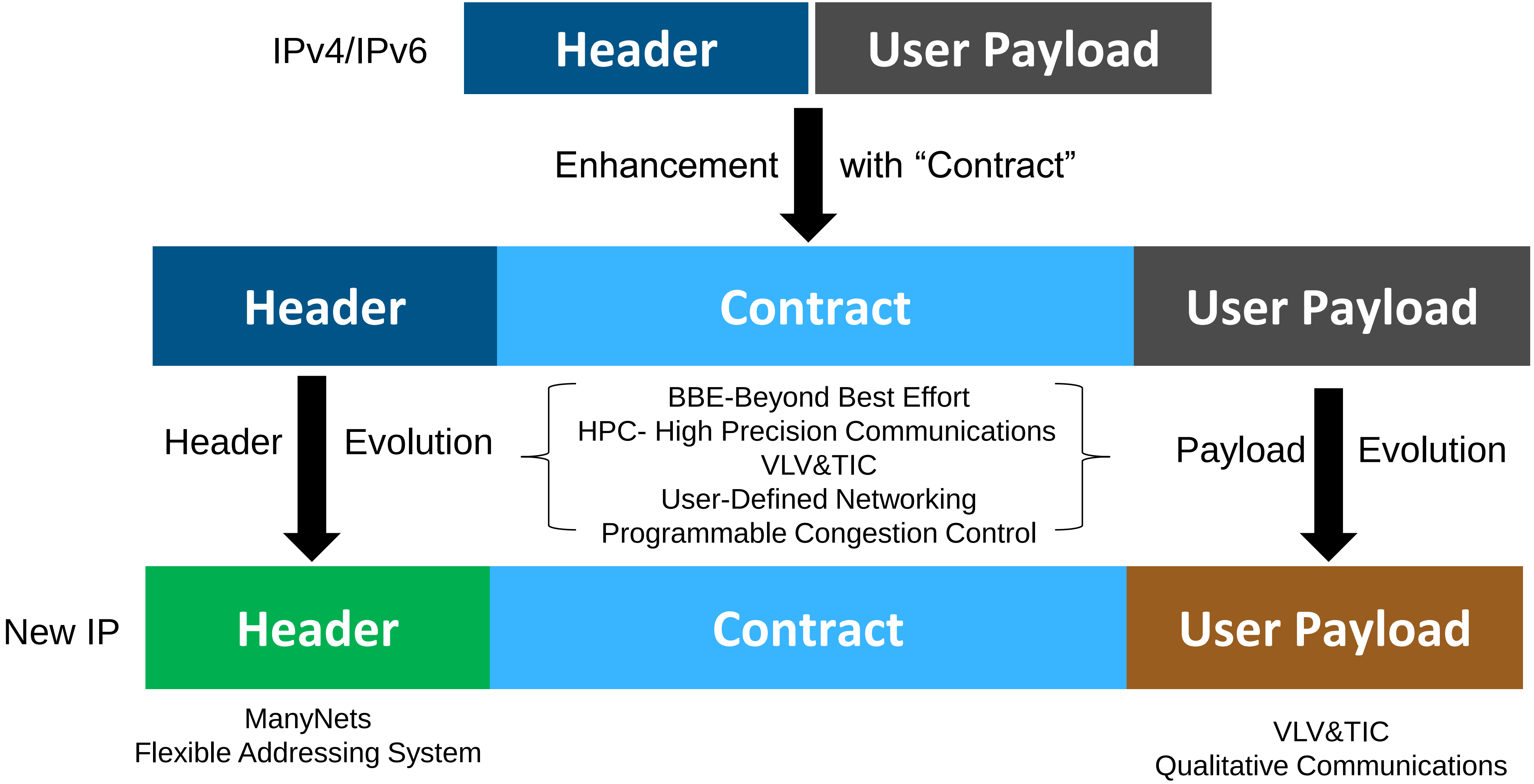


- What is received ≠ What is sent
- In payload, bits and bytes are not equally significant. Instead, they are differential in their entropies
- Less significant bits and bytes may be dropped
- Partial or degraded, yet useful, packets may be repaired and recovered before being rendered
- Good for
  - Large volume of image-like data
  - Holographic type communications
  - Media with digital senses

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

Summary

New IP: Evolution Map



IPv4/IPv6

Header

User Payload

Enhancement with “Contract”

Header

Contract

User Payload

Header Evolution

BBE-Beyond Best Effort
HPC- High Precision Communications
VLV&TIC
User-Defined Networking
Programmable Congestion Control

Payload Evolution

New IP

Header

Contract

User Payload

ManyNets
Flexible Addressing System

VLV&TIC
Qualitative Communications

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

New Technologies

- 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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Mohamed-Faten Zhani
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Mostafa Essa
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Sheng Jiang
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