Network 2030: A New Horizon to the Future Networks

Richard Li, Ph.D.

Chairman of ITU-T Network 2030
Chief Scientist and VP of Network Technologies, Futurewei

A Keynote Speech at InfoWare 2019

Rome, Italy

June 30-July 4, 2019

Contents

Actually, the Internet is a pretty old technology!


Paul Baran   Leonard Kleinrock

Inventor Packet Switching

Frank Heart &Team,

BBN IMP Spec

Queen Elizabeth II

Sends her first email.

TCP/IP
Standardized

ARPANET
ceased

1961 — Conceptual

1968 — Experimental

1976

1980 — Standardization

2000 — Explooooosion

1965

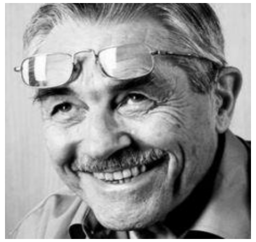
Inventor Packet Switching

Don Davis, NPL, UK

1974

Cyclades at INRIA, France, 1971-1979,

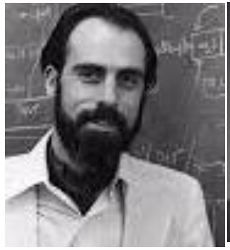
Louis Pouzin



1979

IEEE, "A Protocol for Packet Network Intercommunication" , 1974

Vinton Cerf and Bob Kahn




1989

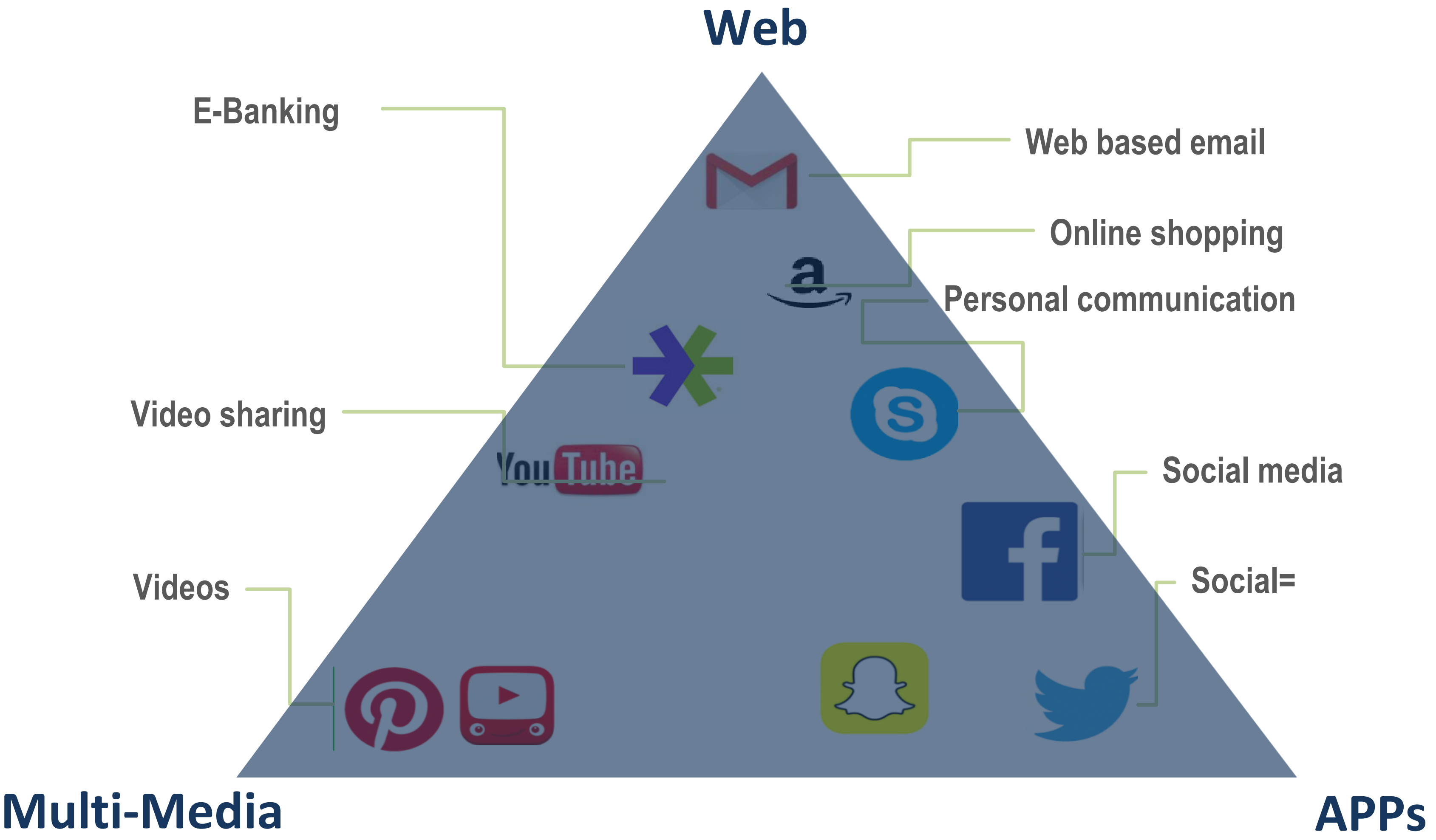
WWW, CERN

Tim Berners-Lee

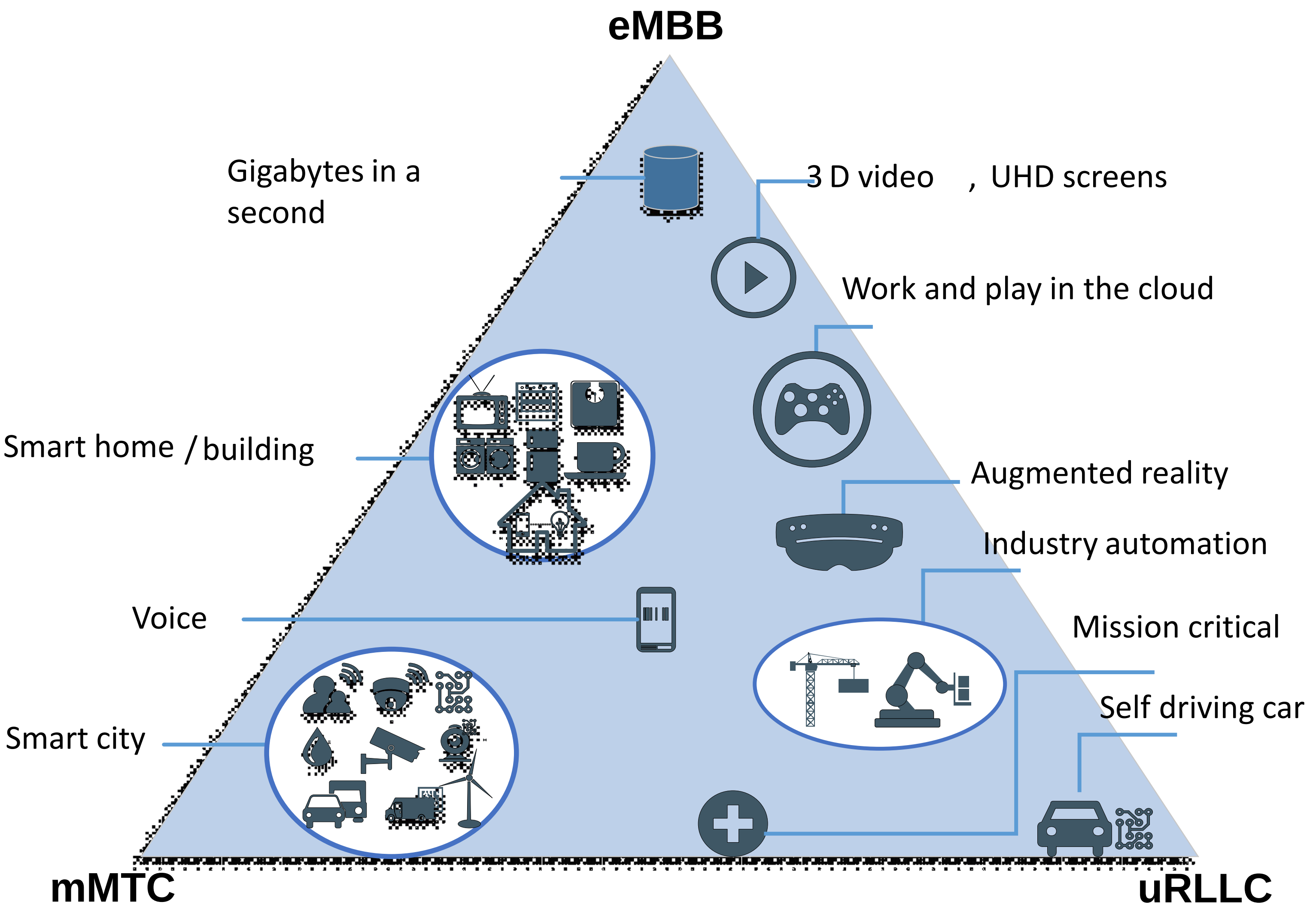
Microsoft Windows

Packet Switching | **Landmark Projects** | **Commercialization**

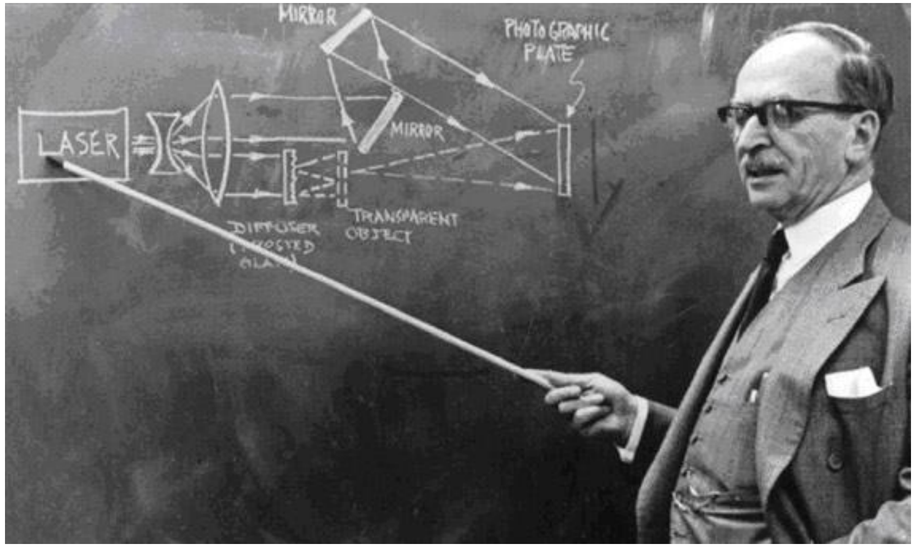
What happened in the last 20 years?



What is happening now?



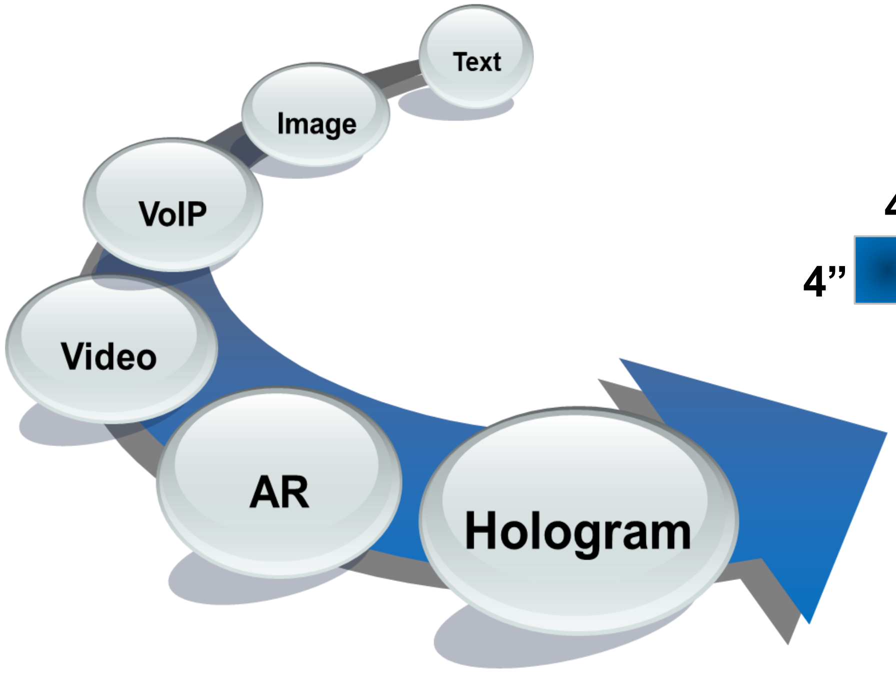
But, what will be happening in the year 2030 and beyond?

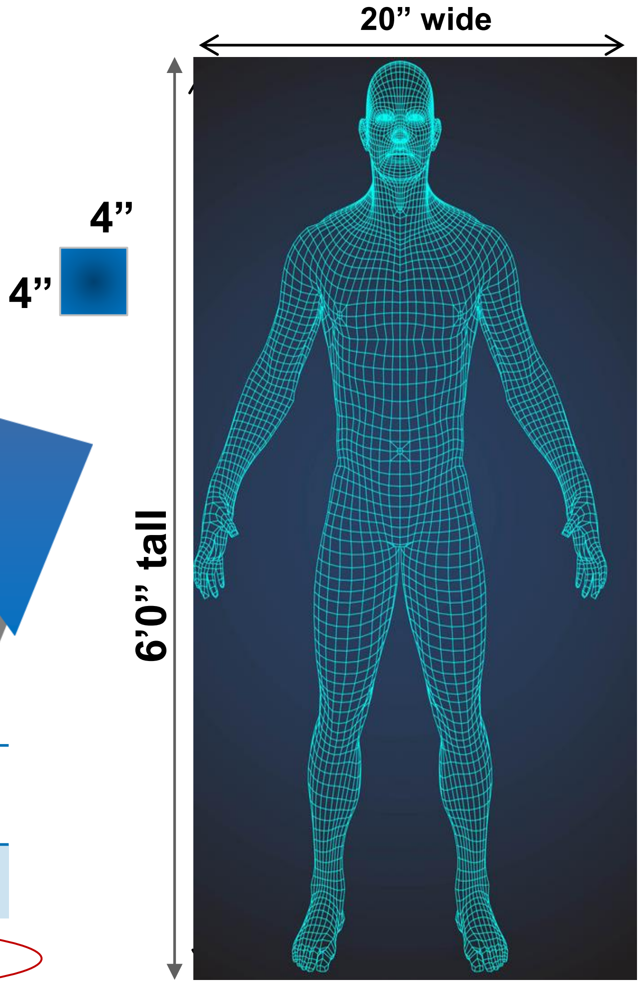


Dennis Gabor, a Nobel Prize Winner:

We cannot predict the future, but we can invent it!

New Media: 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 higher and higher

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

Latency falls down lower and lower

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

Synchronization of parallel streams

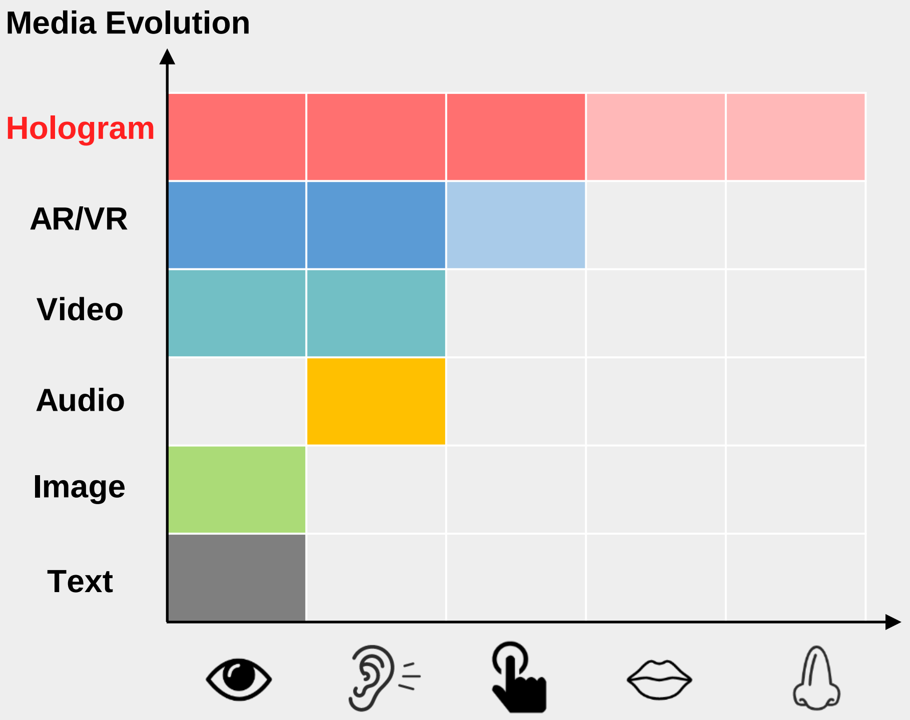
4K/8K HD		VR/AR		Hologram
Audio/Video(2)	streams →	Multiple tiles (12)	streams →	~thousands (view-angles)

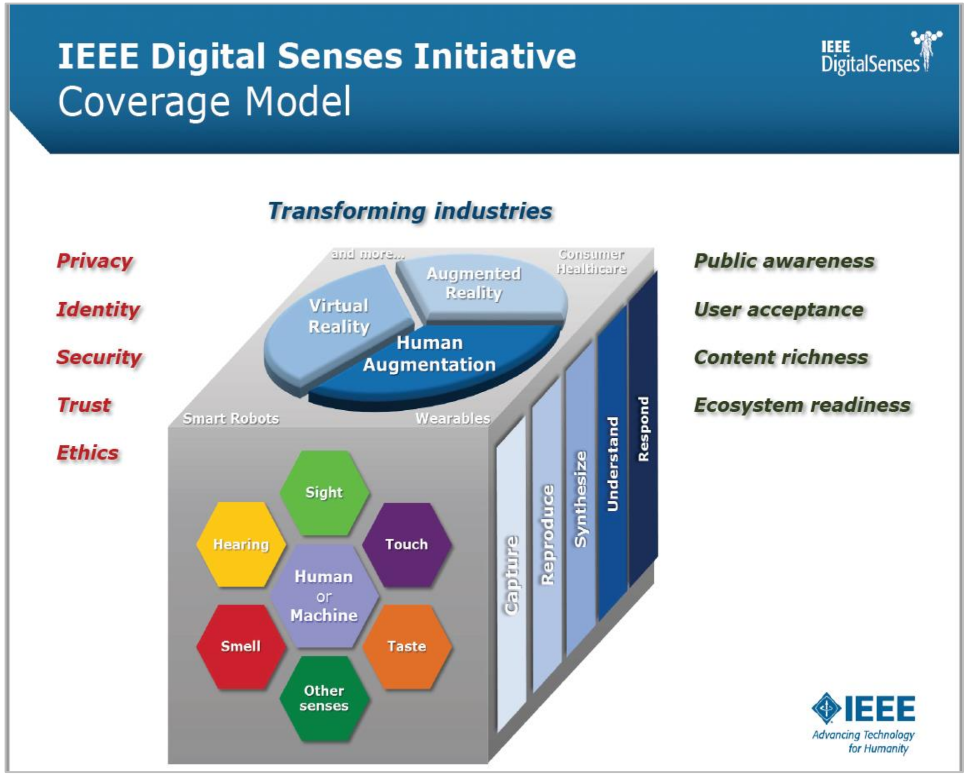
Digital Senses and Digital Reality



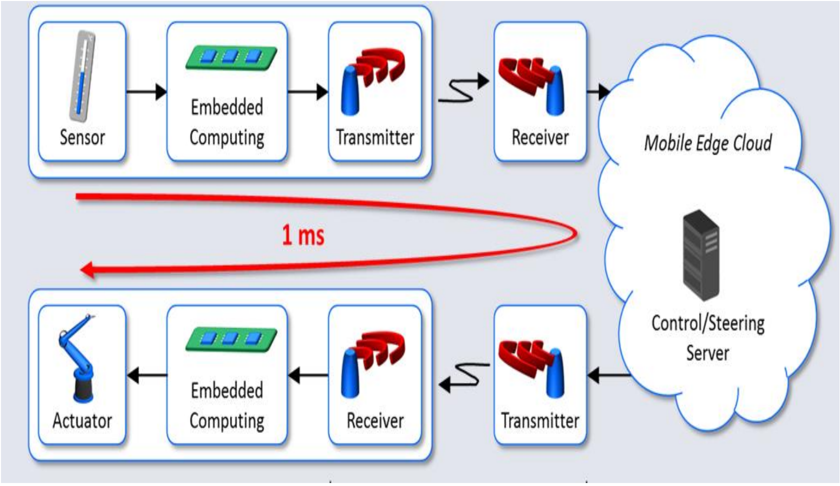


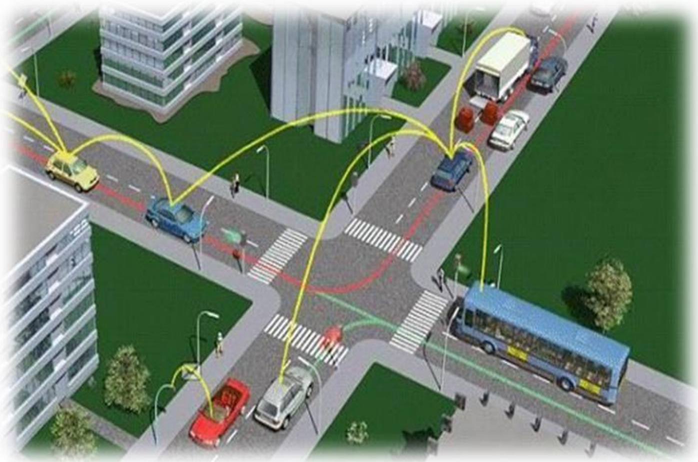
1T/s	1ms
1G/s	17ms
100M/s	33ms
64k/s	50ms

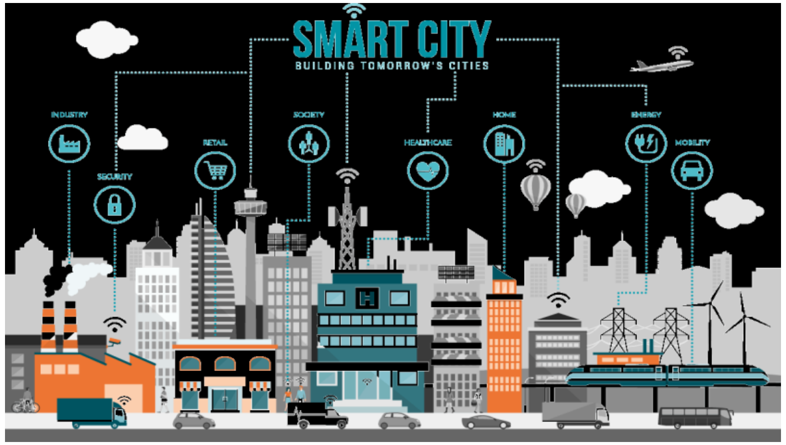


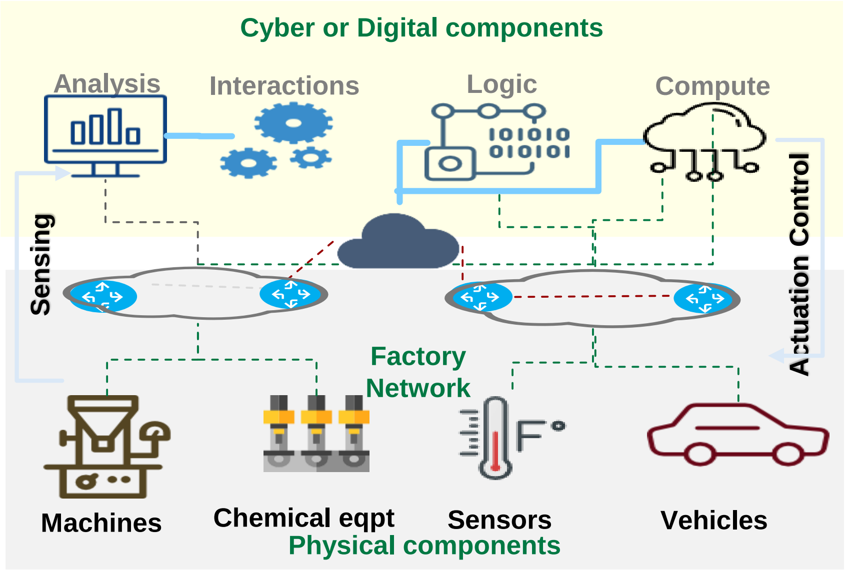


New Vertical Industries: Precision in Communications







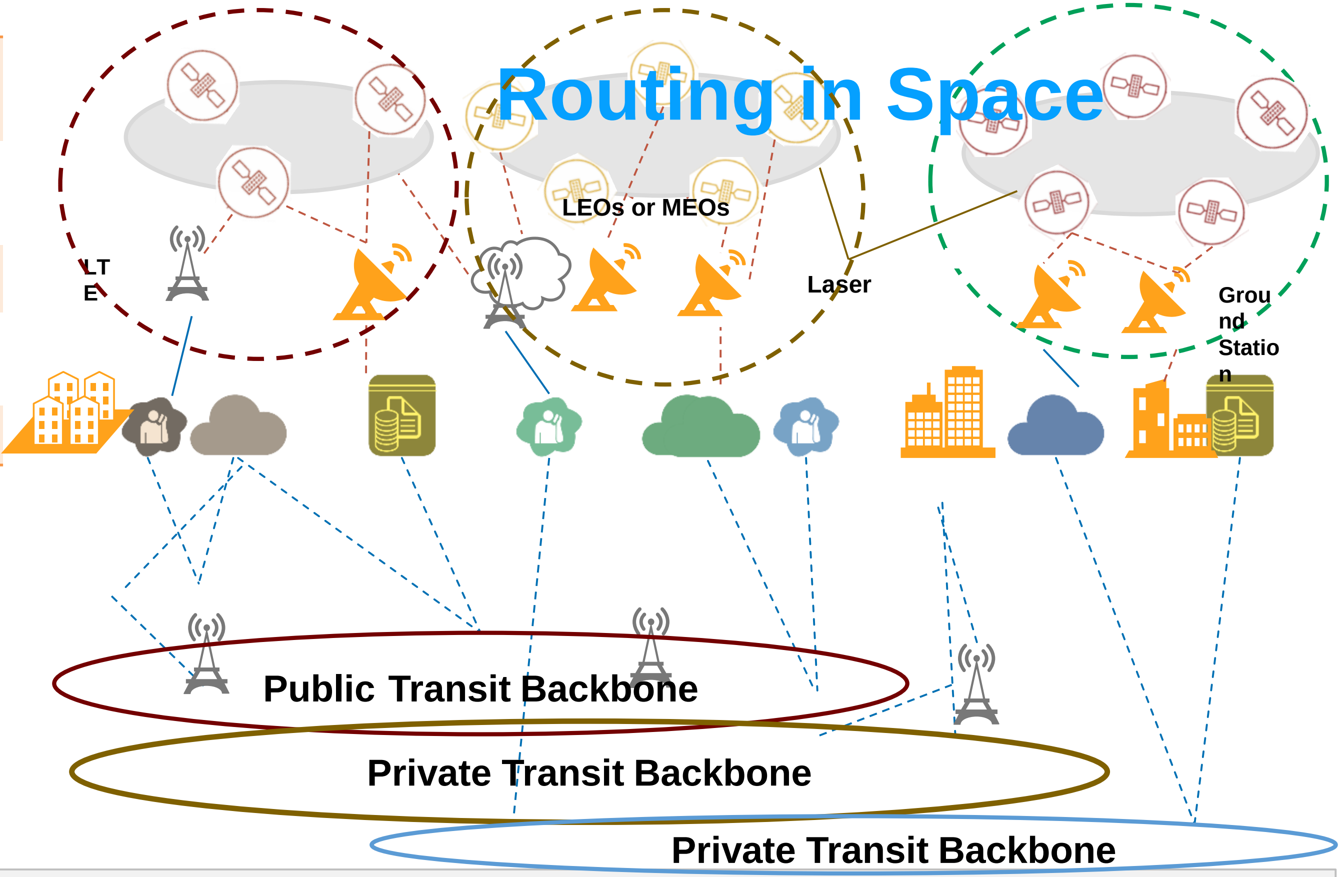


Source of pictures: the Internet

New Infrastructure: Terrestrial and Satellite Networks

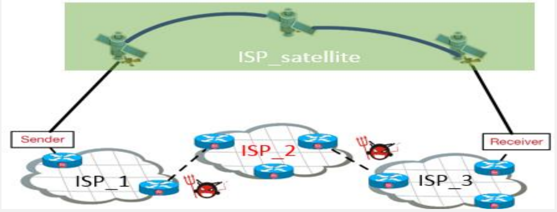
Co.	Support	Scale
Starlink	SpaceX, Google	4K by 2019, then 12K
Oneweb	Blue Origin (Bezos), Virgin Orbit	650 by 2019
Boeing	Apple (spec)	2956, 1350 in 6 yrs
O3Nb	Virgin group, SES	400
CASIC	China	300 (54 trial)

Distances	Bandwidth	delay
(LEO) 900-1200 KM	1—200 Gbps	35ms
(MEO) ~2000 KM	1-200 Gbps	~60ms
Space to space	~100 KM – ~Tbps ~1000 KM ~10 Gbps	




Emergency relief

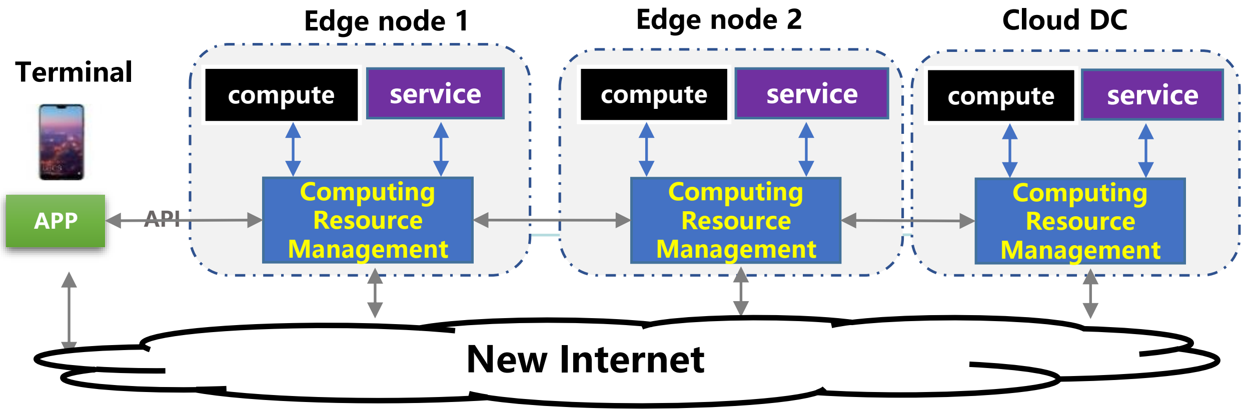

High-speed aviation and navigation broadband



Cross-border secure transmission

New Infrastructure: Computing in Networks

Trend 1: Ubiquitous computing power, at different distances & different scales

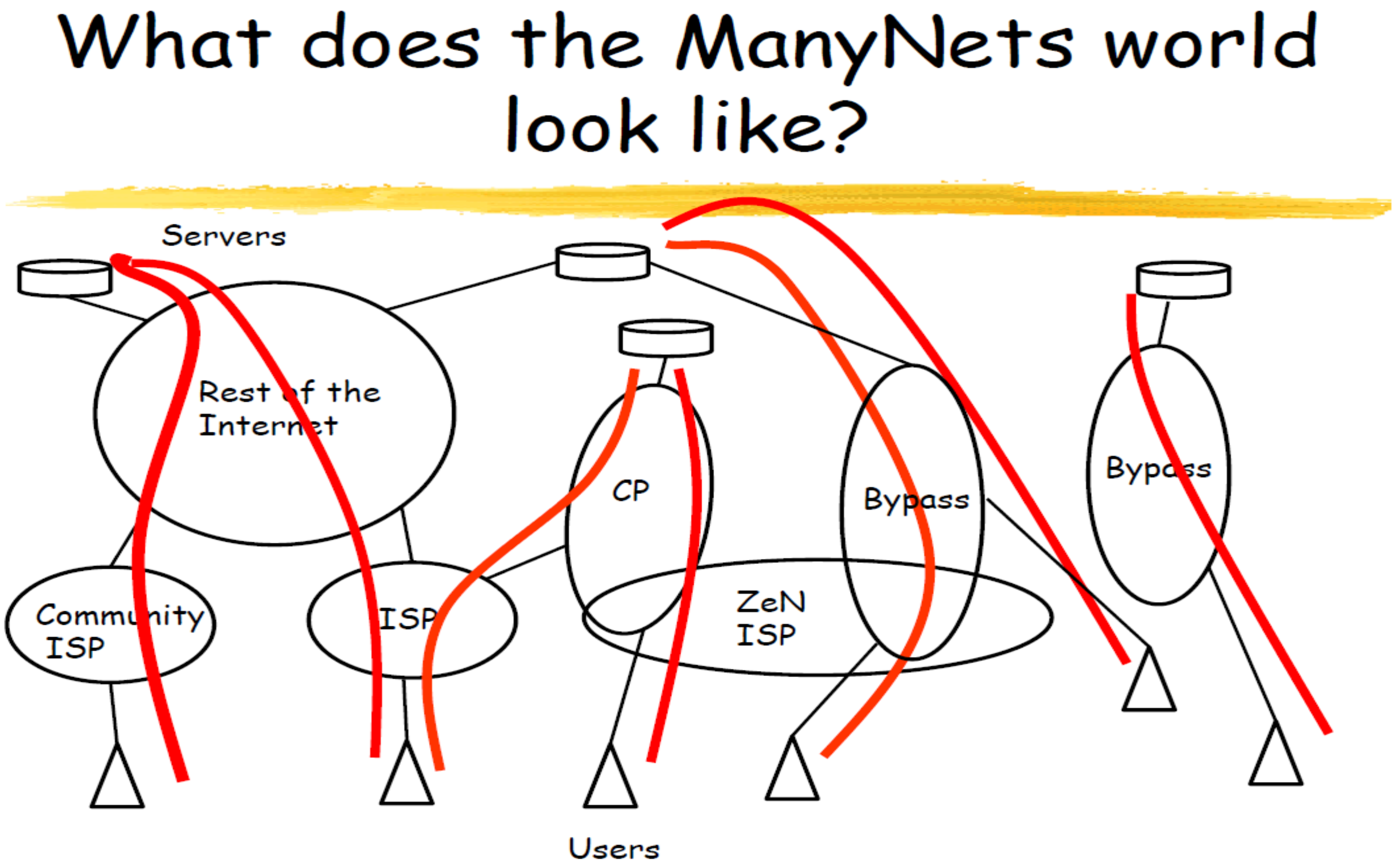


Trend 2: Ubiquitous functions: Micro-service and Serverless

- **Client side: Focus on service logic without sensing computing locations and resources.**
- **Server side: The event trigger function component can be used immediately after it is used up.**

- ❖ **Economic reason**: Putting servers closer to users could save bandwidth and traffic in the Internet
- ❖ **Technical reason**: Some applications require short latency. Putting the server at the edge would shorten the communication distance, and therefore shorten the latency
- ❖ **Functional reason**: Computing has to be deployed to implement functions like DDOS Prevention

New Infrastructure: ManyNets



- **Sovereignty-based**
  - Balkanized or nationalized Internet
  - Europe's decentralized internets through citizen rights initiatives
- **Business-based**
  - Google Network
  - Facebook Network
  - Content Provider's networks
  - Space Internets
- **Technology-based**
  - SigFox
  - Satellite Internets
  - SpreadNetworks
  - Haste
  - FirstNet

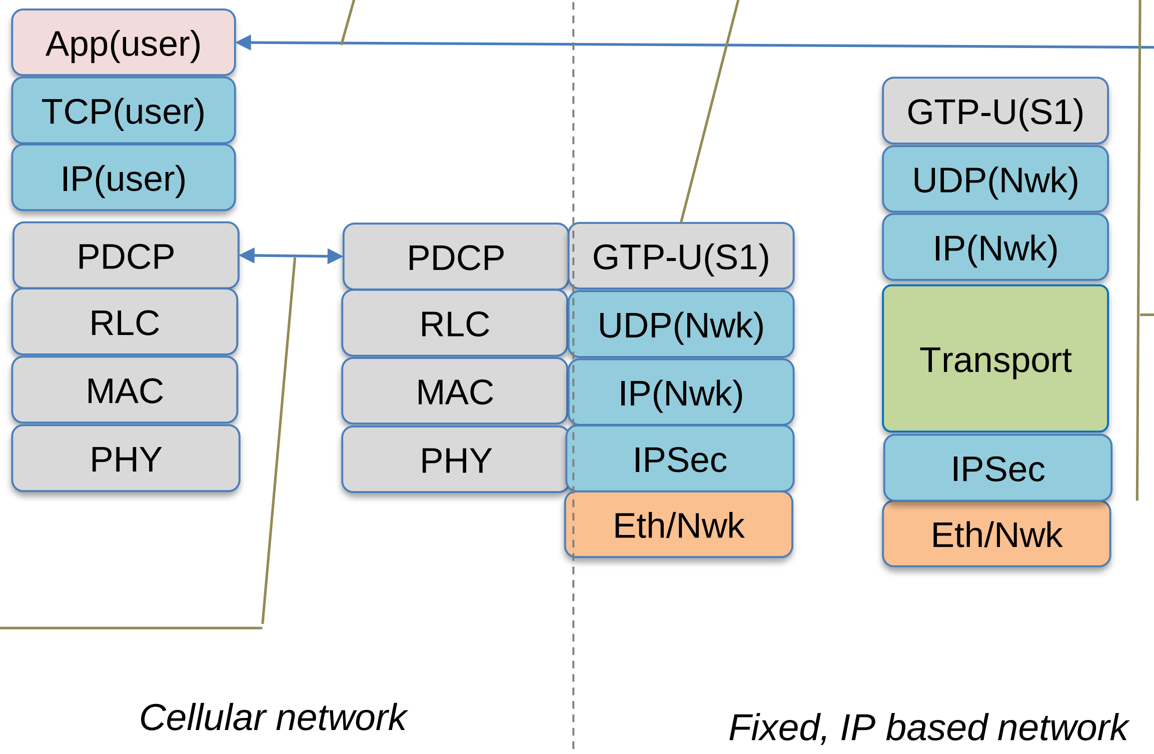
- **Technical Challenge:** how to make them converge and cooperate?
- **Regulatory challenge:** should they be converged or regulated?

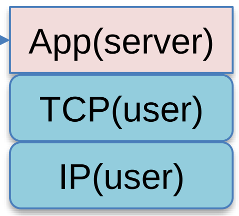
Sources: Mostafa Ammar, The Service-Infrastructure Cycle, Ossification, and the Fragmentation of the Internet, 3rd ITU Workshop on Network 2030, London, Feb 2019

5G/B5G demands a business-synergic mobile backhaul, but

Throughput and latency are not guaranteed by the current end-to-end TCP/IP

GTP and its underlying transport altogether create holistic awkwardness and inefficiency without coordination





Delay variations: Radio retransmissions are not synchronized with TCP flow control, causing TCP to wastefully retransmit packets

Inefficient use of protocols

- Tunnels over tunnels
- Some header fields repeat each other

Not suitable for mMTC and uRLLC

- Header taxes are high, sometimes as high as 90%, making it unsuitable for mMTC and short messages
- No end-to-end QoS, making it unsuitable for uRLLC

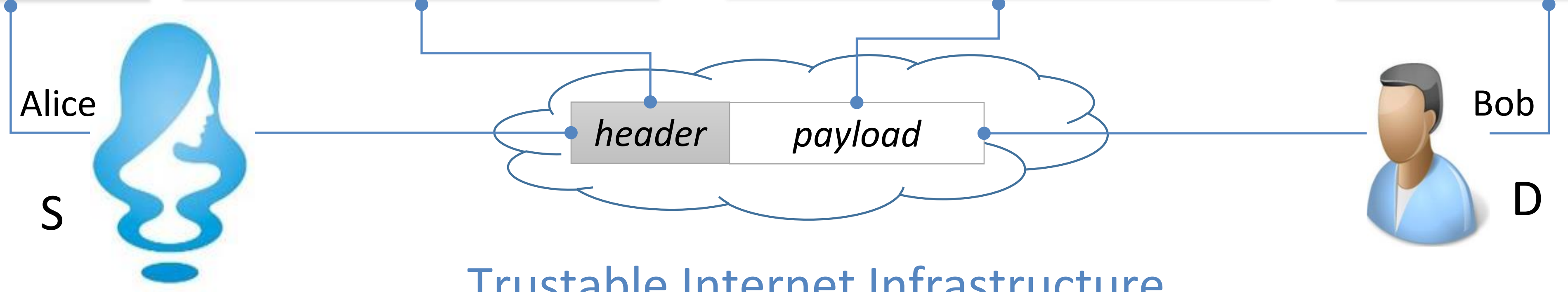
Privacy and Trust

Authenticity
Source IP spoofing

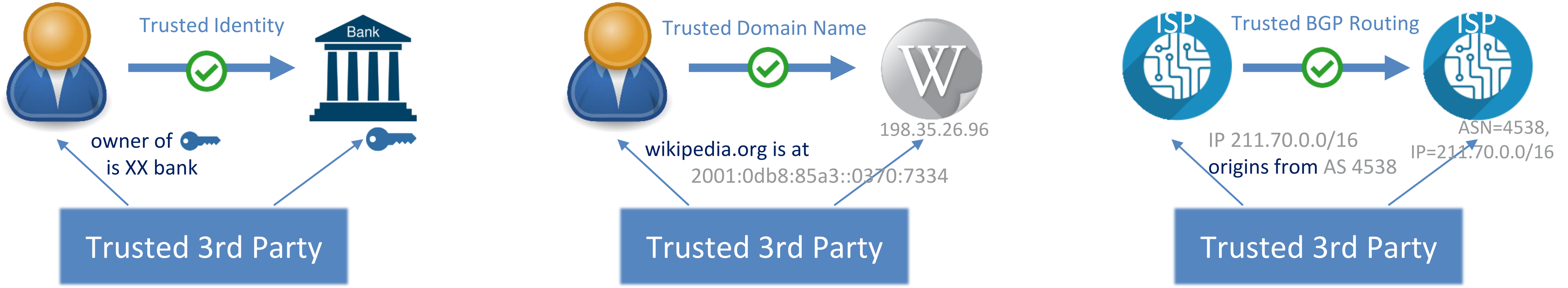
Accountability vs. Privacy
Exposing IP, port & TTL on wire decreases privacy, but anonymizing them decreases accountability

Confidentiality & Integrity
IPSec & TLS can protect payload sniffing or tampering. But the key exchange process has vulnerabilities.

Availability
Anyone can send DDoS traffic to overwhelm targets' bandwidth, CPU or memory.



Trustable Internet Infrastructure



Are we ready for the year 2030 and beyond? No, absolutely not!

New Requirements and Drivers

Precision of time in services
- Industrial Control
- Autonomous Driving
- Tactile Internet

Holographic media
- Real-time high-throughput streaming
- Coordination of different streaming

ManyNets Infrastructure
- Space Internets
- Private Internet
- Unresolved Regulatory barriers

Moving beyond best effort
- Premium services
- Privacy and Trust
- Lossless networking

Rich Access Technology
- Gbps/Tbps access enabled by 5G/B5G and Surface Wave

In the last 20 years, four major technologies have appeared: IPv6/SRv6, MPLS, SDN, and NFV:

1) **IPv6 changes the addressing scheme, while SRv6 reformats source routing**
2) **MPLS turns routing into switching, and is used to implement traffic engineering and VPN services**
3) **SDN changes the way to control networks**
4) **NFV changes the way to implement network functions**

But none of the above would change the nature of the Internet:

- **Statistical multiplexing**
- **Best-effort forwarding**

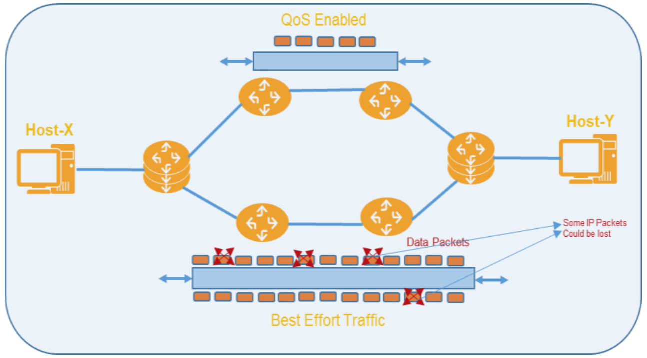
Current technologies can't support Premium-Class Networks

- Per-Hop Behavior
- Forwarding Path (Source Routing)
- Minimal Bandwidth

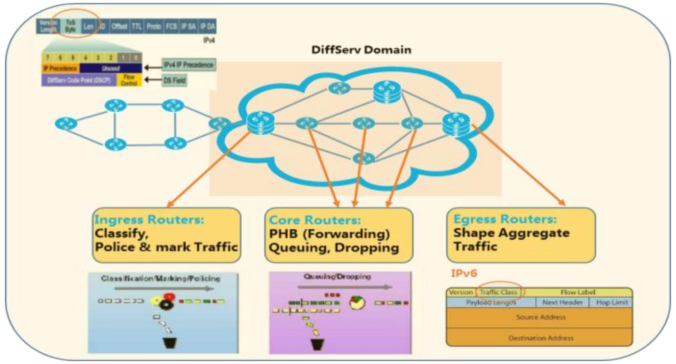
- Fails: Throughput guarantee
- Fails: Latency guarantee
- Fails: Losslessness
- Fails: Zero Jitter
- Fails: Privacy and Trust

All the Current Technologies

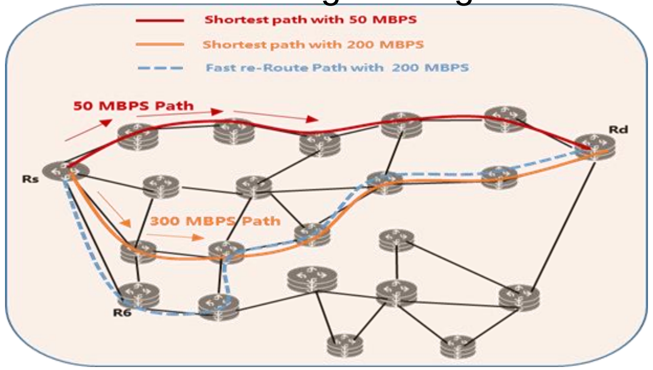
Best Effort



Differentiated Services



Traffic Engineering



We are reaching the Cerf limit!

Semi-Conductor	Information Theory	Internet Technology
Moore's Law: (摩尔定律) The number of transistors in a dense integrated circuit doubles every two years As of 2017: 18 billion transistors on a 48 core Qualcomm SoC	**Shannon–Hartley Theorem**: (香农定律) $C = B\, log_2\, (1 + \frac{S}{N})$ It specifies the maximum rate at which information can be transmitted over a communications channel of a specified bandwidth in the presence of noise	**Cerf-Kahn-Mathis Theorem**: (瑟夫定律) $\mathbf{T \leq min(BW, \frac{WindowSize}{RTT}, \frac{MSS}{RTT} \times \frac{C}{\sqrt{\rho}})}$ It specifies the maximum throughput at which data can be transported over a path of a specified bandwidth in the presence of round-trip time, packet loss, and flow control window size.

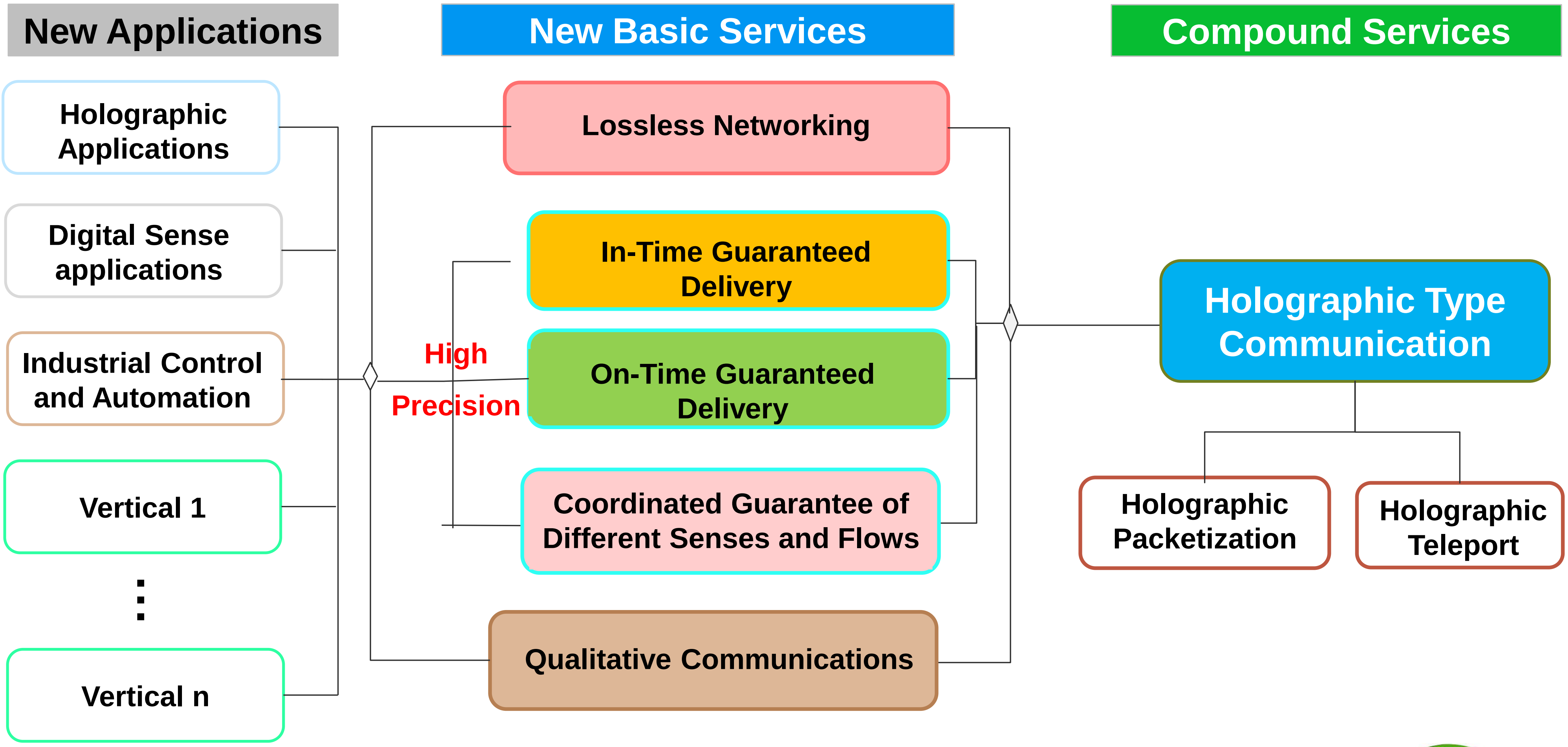
Example (source: Richard Li, Keynote Speech at IEEE NetSoft 2018, Montreal, Canada, 2018) :

Given: Packet loss: 1 packet every 10,000 packets; Throughput: 12Gbps

Then, the delay will be 114 micro-seconds, nearly impossible in the reality.

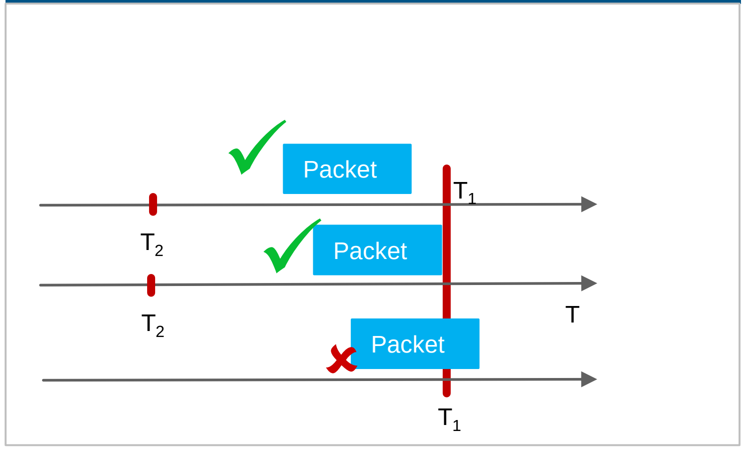
Conclusion: Applications like AR/VR in the range of 10 Gbps can't run on the Internet. We are reaching the Internet limit.

New Network Layer: Going beyond Best-Effort



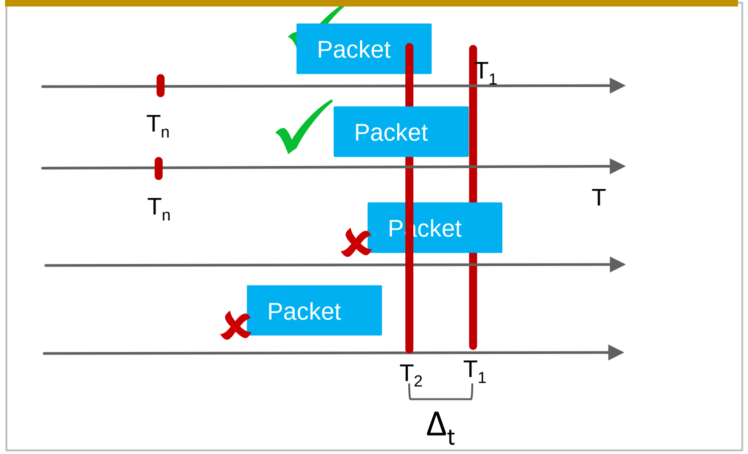
New Services: High-Precision Communications

In-time Guarantees



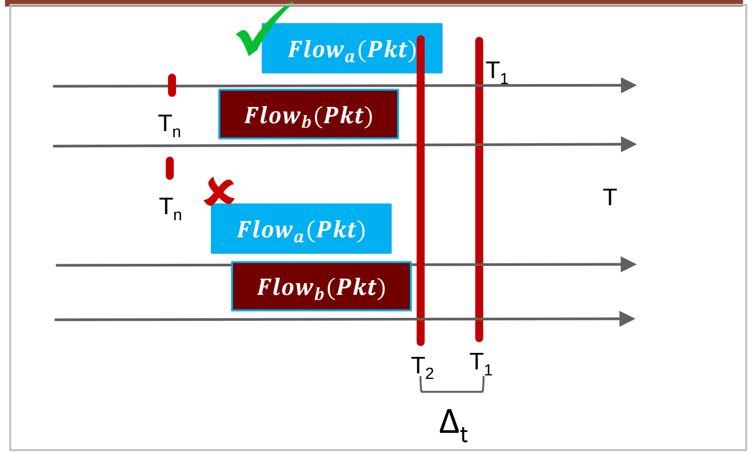
Bounded Latencies: Deliver on or before specified time. Bursts are possible

On-time Guarantees



Bounded Time Interval (Δ_t may be 0): Deliver within specified and generally small arrival variance

Coordinated Guarantees



Packets of two or more flows and streams arrive in a coordinated in-time/or-time guaranteed way

Latency (us) = Distance (km) × τ + Θ, where

τ = 5 (Y. 1541)

Θ is the processing delay

Coordinated | On-time | In-time | High Precision Communications

Latency Precision Attributes

Cause for Delays: Transmission, Propagation, Processing and Queuing

Adaptiveness: to congestion and inter-related flows

Precise measures: Rate of flow, extremely low latencies for critical events such as accident avoidance

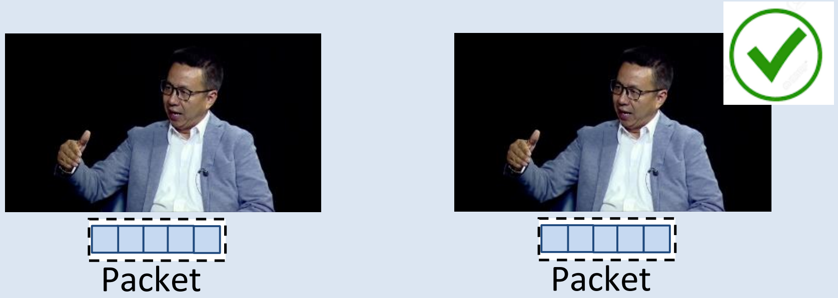
Delay variation : Jitter may need to be near zero or extremely low for critical events such as industrial control

Going beyond the Cerf limit: Qualitative Communications

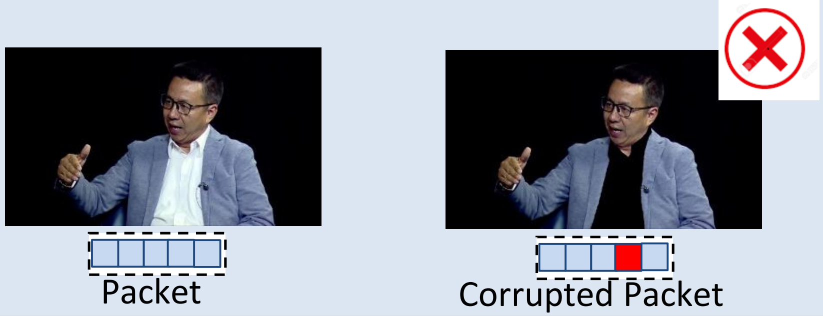
Current: Quantitative Communications

Sender | Receiver

What is sent = What is received

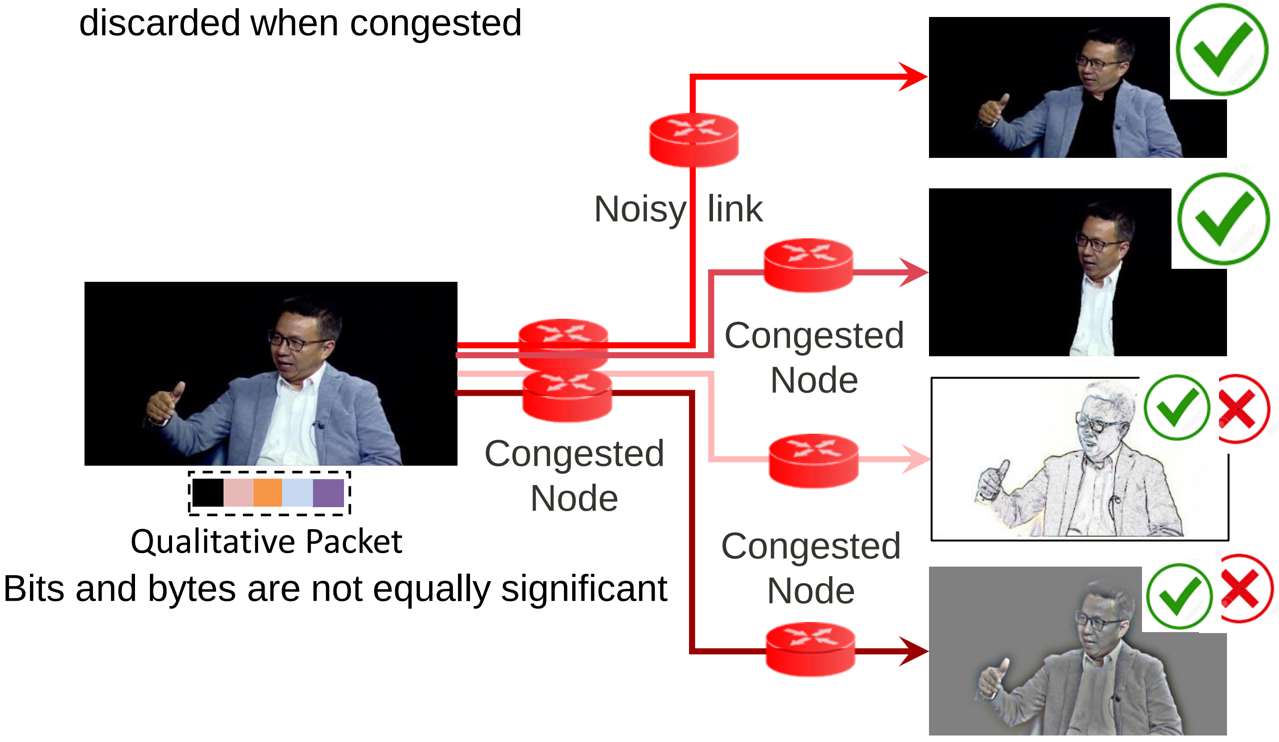


If they are not the same, the sender retransmits it until the receiver gets exactly the same copy

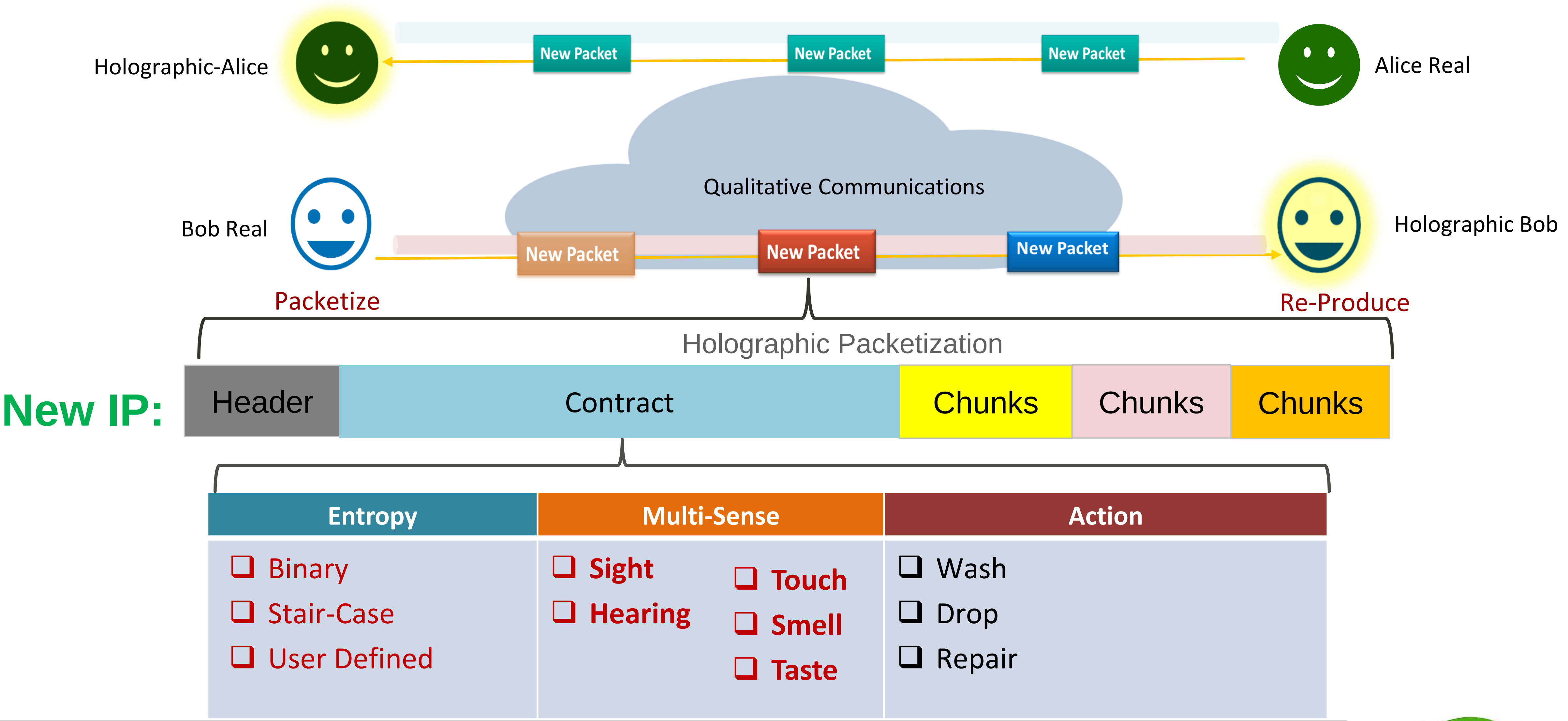


New: Qualitative Communications

- What is received is not required to be exactly the same as what is sent, accepting partial or degraded, yet useful, delivery of a packet
- What is received may be repaired and recovered before being rendered
- Intermediate routers may drop less significant chunks to avoid being discarded when congested



Non-Linear Packetization and New Services: Holographic Type Communications



Futurewei Technologies, Inc

What are the Missing Pieces?

After a packet is sent, routers don't know

- ❖ Its throughput requirement of the application this packet belongs to
- ❖ Its latency requirement of the application this packet belongs to
- ❖ significance requirement of different parts of the packets

LATENCY
On-time, In-time, Coordinated

THROUGHPUT
Precise, Holographic scale

QUALITATIVE
Packets with different significance

Since routers and switches don't know what is asked for, they can not meet the requirements on throughput, qualitative significance and latency.

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 grandfather’s postal service.

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

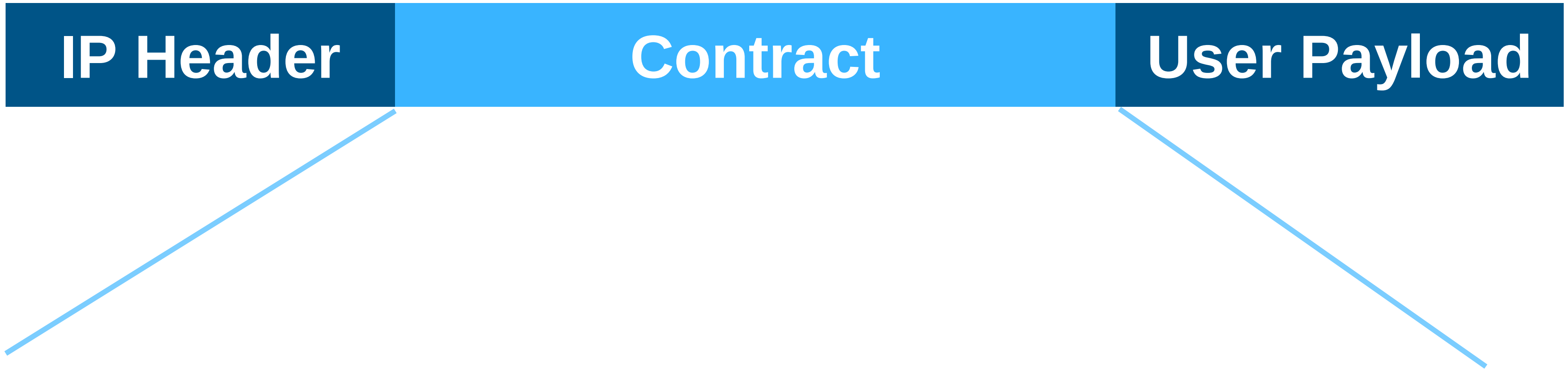
Billable

Trackable

Customizable

Assurable

Let’s imagine a new IP packet as a “FedEx-gram”



- **Provide a contract from an application to the network**
- **The network and routers process the contract**
- **Packets are processed per computational multiplexing (as against statistical)**
- **Support new communication services**

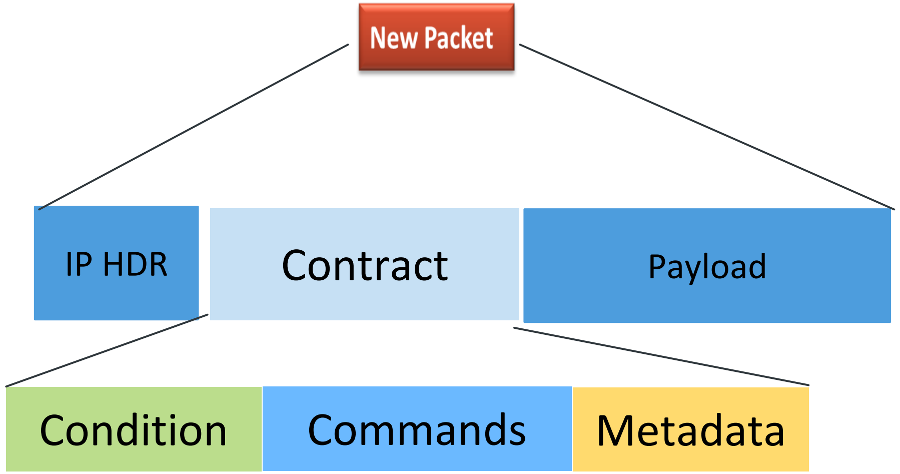
Ref: Richard Li, et al, A New Framework and Protocol for Future Networking Applications, ACM Sigcomm 2018 NEAT Workshop, Budapest, Hungary, August 2018

Implications of New IP on Routing Nodes?

A Contract manifests into a set of commands and meta data by application

- **Commands are executed as specified**
- **Traditional routing is assumed by default**
- **User Data: must not be changed**
- **Meta Data: The contract may contain some meta data. These meta data may be by commands within Contract.**

High Precision Data Plane - Beyond Best Effort



Achieve High Precision Communication Services on per ‘New IP Node’ basis.

Tasks and Elements in Contract

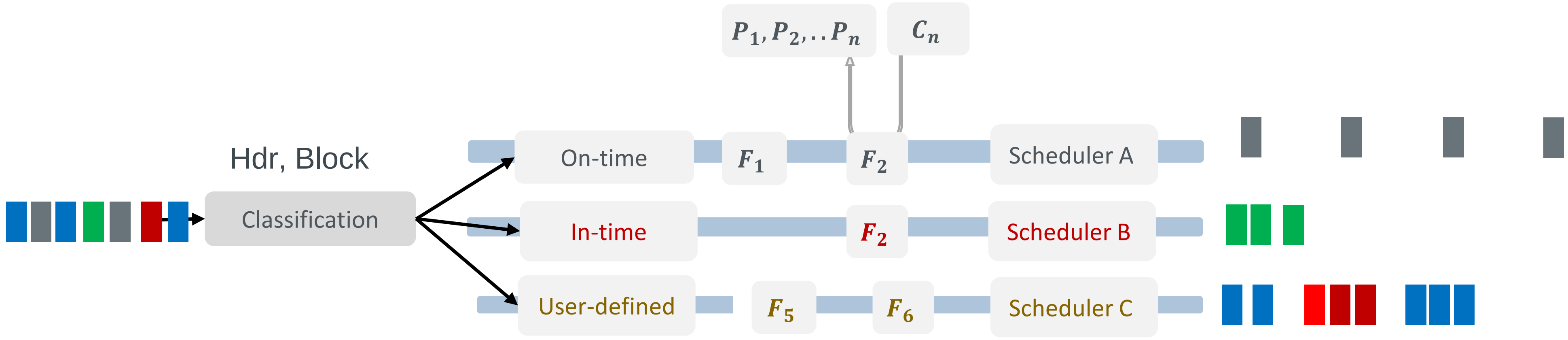
Measurable:
- Bandwidth
- Latency
- Jitter
- Clock Sync
- Time Slicing
- Observe

Qualitative:
- Packet Entropy
- Multi-Sense

Extensible:
- In-Network Actions
- User Defined

New IP Metadata
- Parameters
- Quantity
- Reference

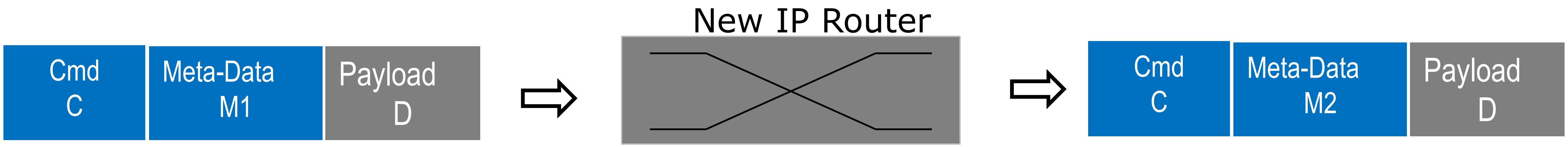
New IP Conditions
- Criteria
- State



Customize packet forwarding processing pipelines with fine granularity

All New IP nodes in network perform forwarding, scheduling, policing as specified in the packet.

New Concepts, New Architectures, New Solutions

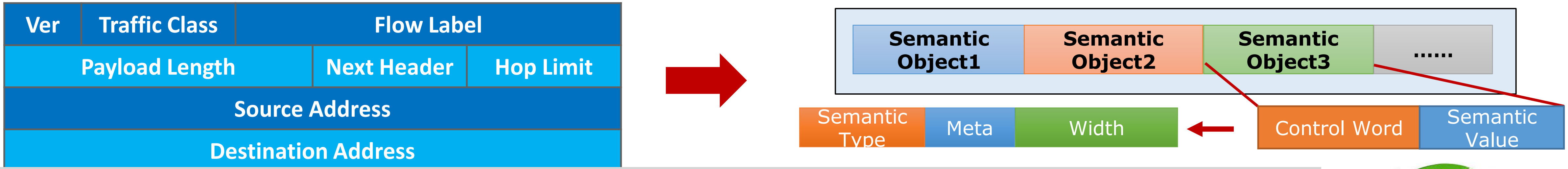


Big Packets: a holistic network layer

- Packet-level Service level objectives: User defined objectives from end-hosts translated in to network.
- in-band signaling: for network operator’s objectives - OAM/telemetry
- ID-Oriented Networking: To manage scale and mobility

Flexible IP: network layer with variable length header

- Applicable for IoT and all future address extension and reduction

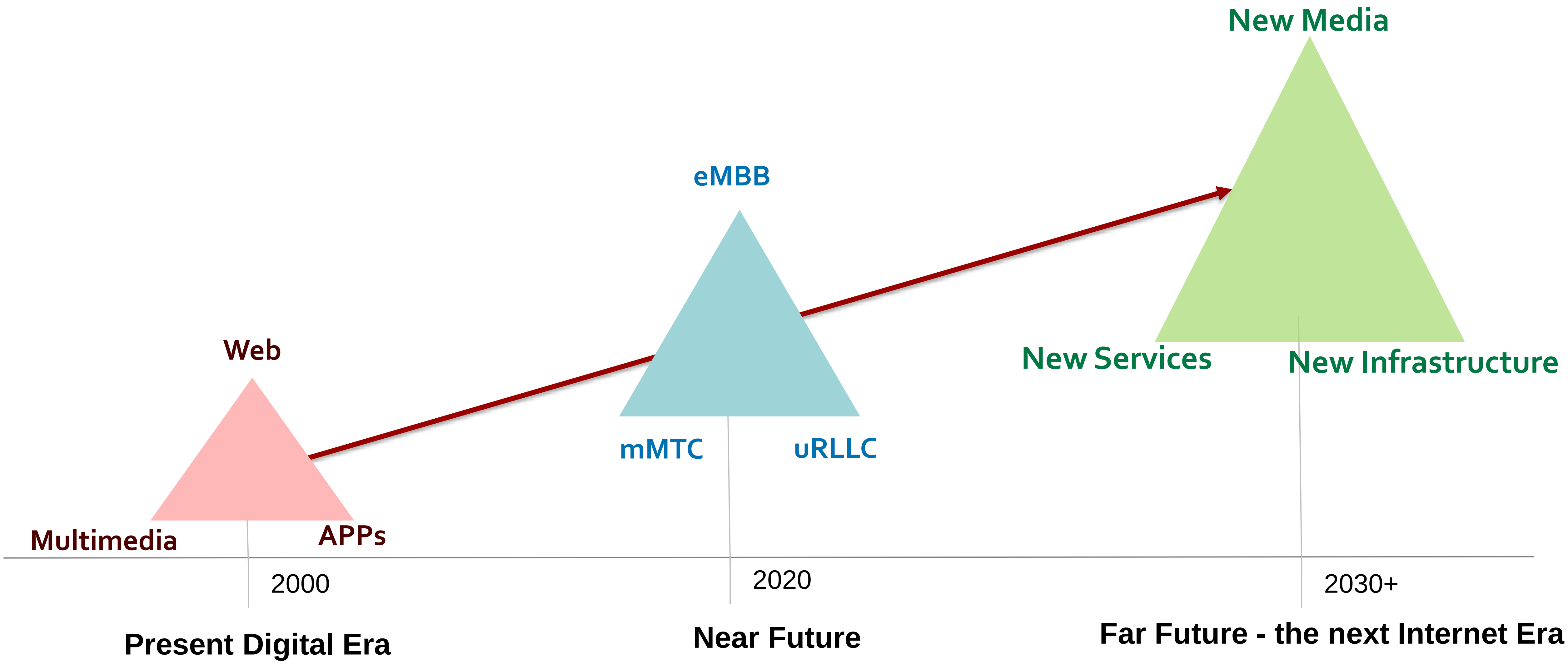


Summary:

Major Challenges

Fundamental Challenge	How do we break through the Cerf Limit?
Infrastructural Challenges	ManyNets, Federated Networks
	Space and Terrestrial Internets
	In-Network Compute, Privacy & Trust
Premium Class Network	High Throughput (Tbps), Low latency (15ms)
	Losslessness, Zero-jitter
	Privacy and Trust
Technical Challenges	Lossless Networking
	High-Precision Communications
	Holographic Type Communications

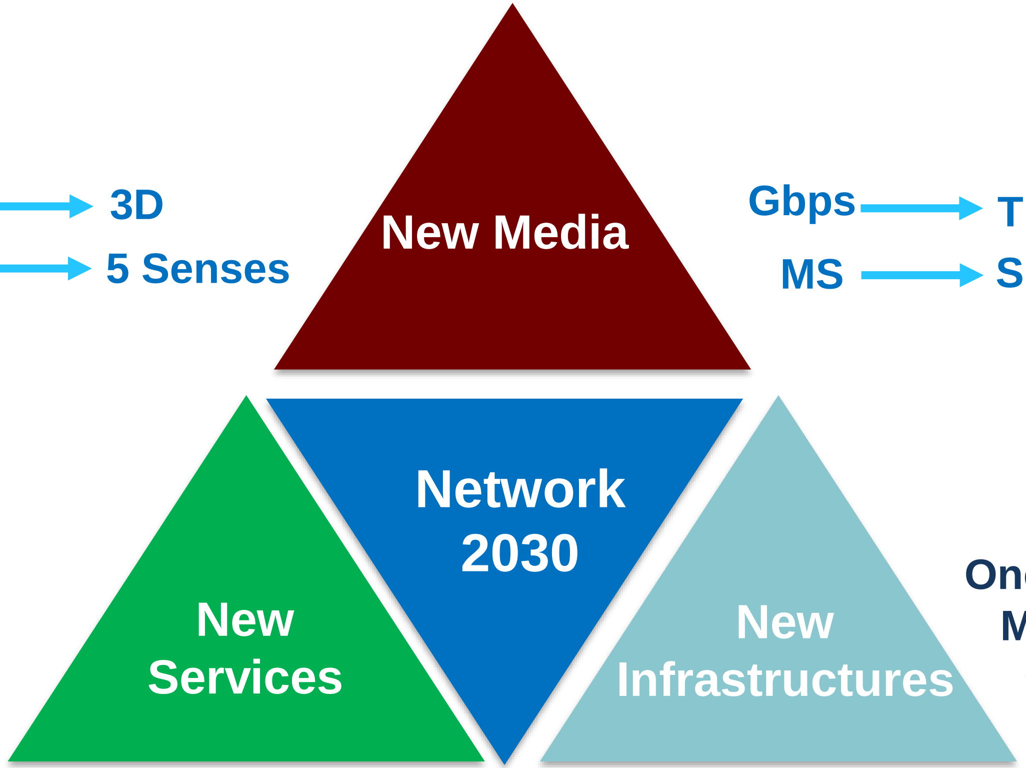
Internet – Past, Present, Future



A New Horizon beyond the Year 2030

Holographic Society and Industry

2D → 3D
2 Senses → 5 Senses



Gbps → Tbps
MS → Sub-MS Latency

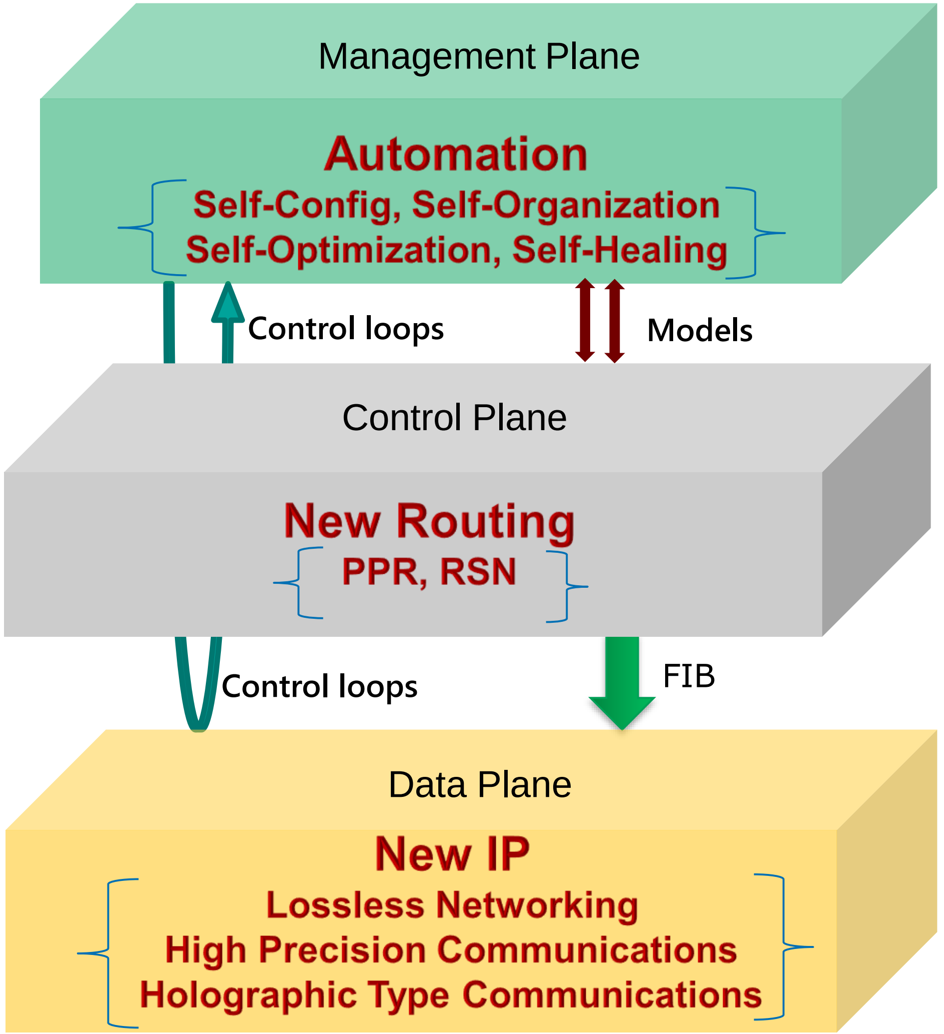
Next wave of
Internet Innovations

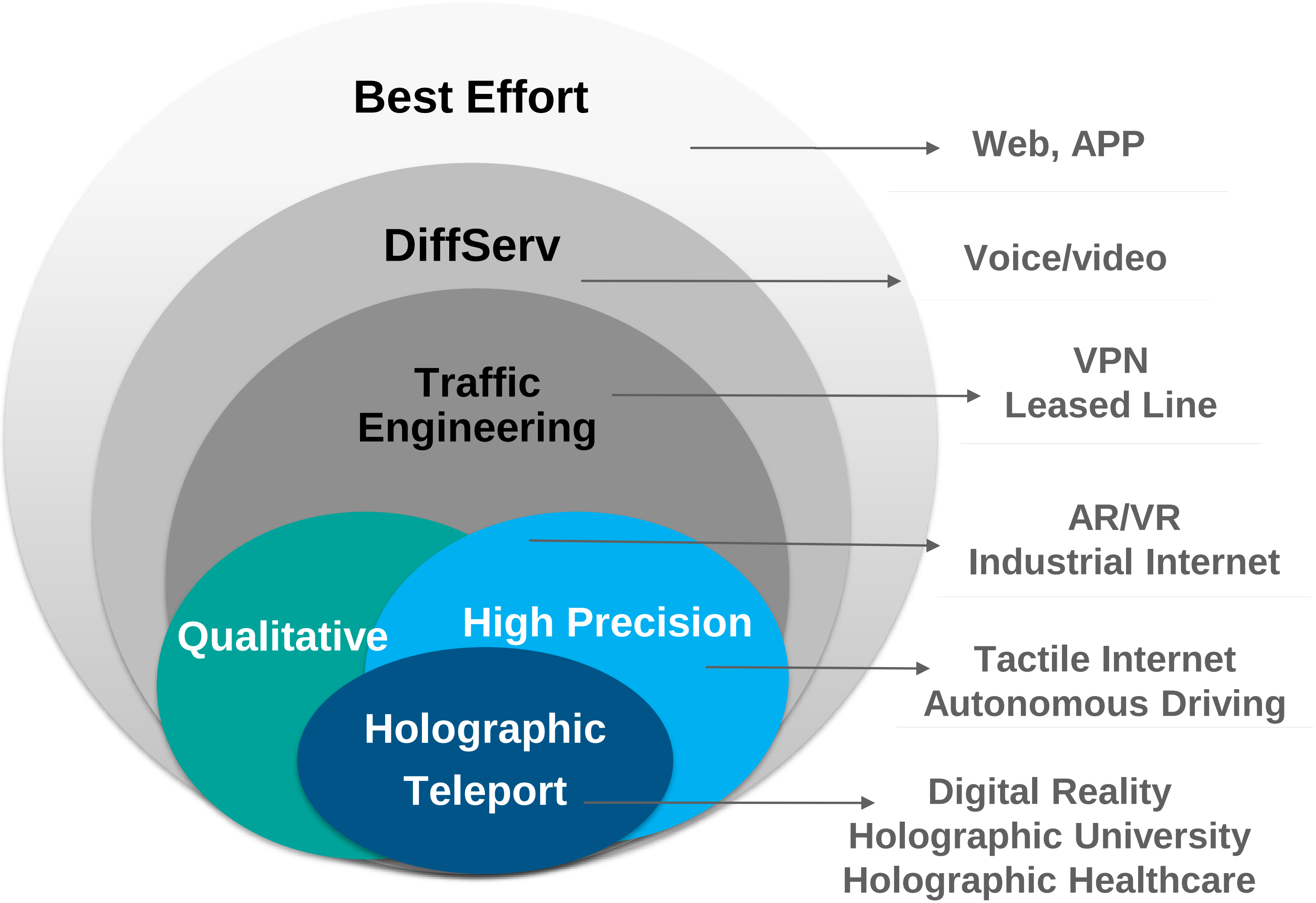
OneNet → ManyNets
Mbps → Gbps/Tbps Access
Computing in Networks

Lossless Networking
High-Precision Communications
Holographic Type Communications

Converged Terrestrial and Space
Fidelity and Trust
ManyNets and/or Federated Networks

Towards a New Internet





Selected Publications and Talks

Concepts

- 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

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

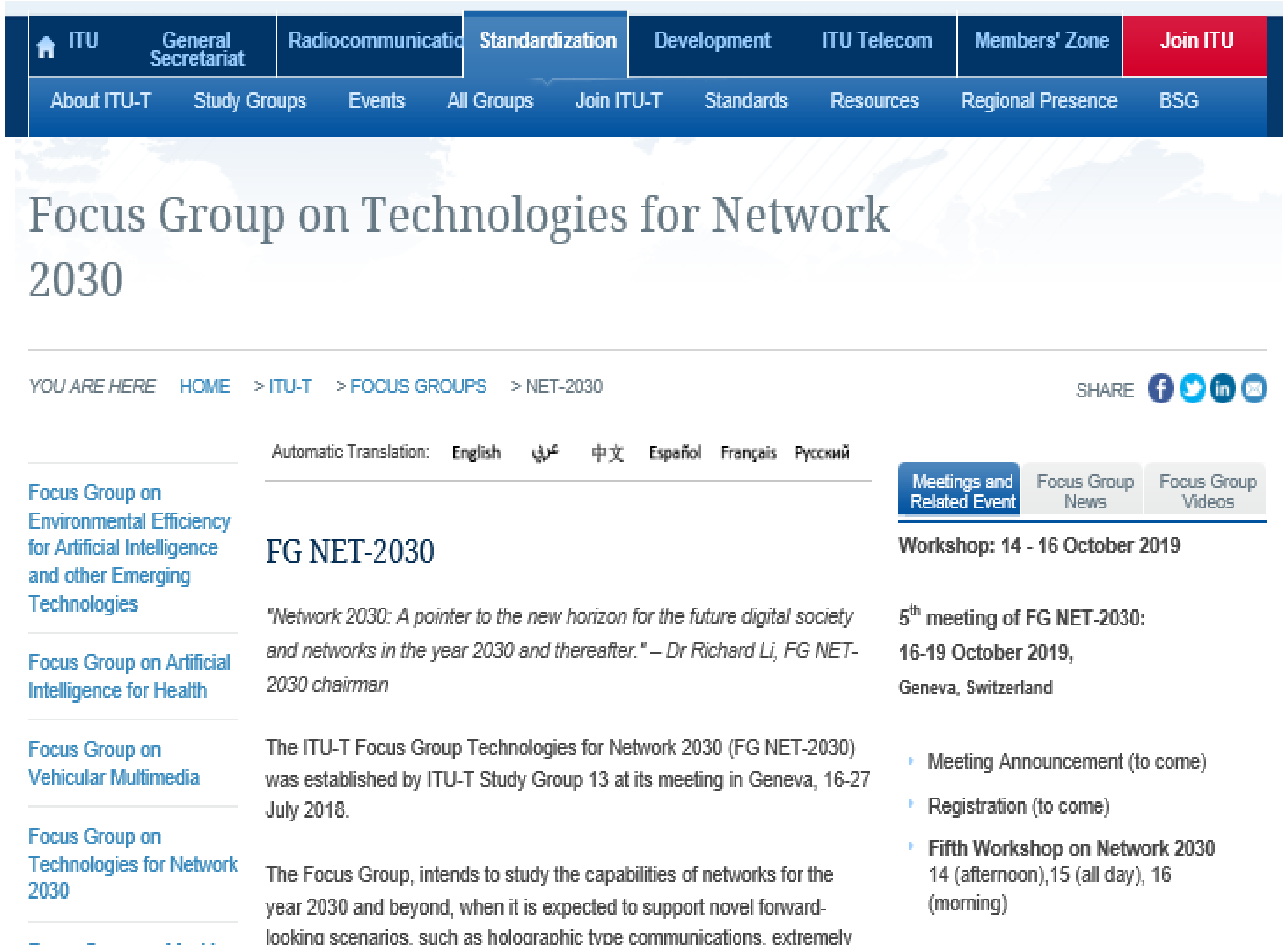
New Technologies

- 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

ITU-T Focus Group on Network 2030



- ➢ To study the capabilities of networks for the year 2030 and beyond, when it is expected to support novel forward-looking scenarios, aiming to answer questions on what kinds of network architecture and enabling mechanisms are suitable for such novel scenarios
- ➢ To explore new communication mechanisms from a broad perspective, that is not restricted by existing notions of network paradigms or to any particular existing technologies
- ➢ Network 2030 may be built upon a new or refined network architecture.

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

Objectives of ITU-T Network 2030

- To study, review and survey existing technologies, platforms, and standards for identifying the gaps and challenges towards Network 2030, which are not supported by the existing and near future networks.
- To formulate all aspects of Network 2030, including vision, requirements, architecture, novel use cases, evaluation methodology, and so forth.
- To provide guidelines for standardization roadmap.
- To establish liaisons and relationships with other SDOs.

Expected Outcomes of ITU-T Network 2030

- To identify the gaps and challenges which are not supported by existing and near future technologies like 5G/IMT-2020, including new network layer or new network architecture.
- To identify performance targets of Network 2030 that is beyond the limitation of existing and near future networks including 5G/IMT-2020.
- To make a report on the definitions, terminologies and taxonomy for Network 2030 and the relevant eco-system.
- To describe the potential architecture and framework of Network 2030.
- To analyze the backward compatibility and steps towards Network 2030, based on existing and near future networks including 5G/IMT-2020.
- To study the future scenarios and use cases.
- To draft a report on describing the standardization gaps for ITU-T study groups.
- To organize thematic workshops and forums on Network 2030, which will bring together all stakeholders, and promote the FG activities and encourage both ITU members and non-ITU members to jointly contribute on this work.
- To make liaison with other SDOs.

Meetings 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





Thank You!

I welcome and invite you to join us to build a New Internet

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

Appendix

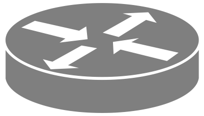
What is next?

5.0

?

4.0

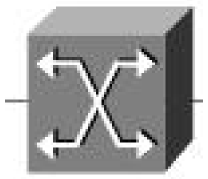
IP



Connection-less, distributed, variable packet length

3.0

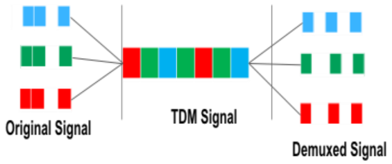
ATM



Connection-oriented, Fixed-size cells path setup

2.0

TDM



Multiplex Information into single channel

1.0

Analog

Circuit Switching	Multiplex Switching	Cell Switching	Packet Switching	?