IP 2020: Advancing to the Next Generation Internet

A Discussion on Breaking Current Internet's Limitations

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HUAWEI

Purpose of This Talk

- I want you to know **that the current internet is nearing its limit**
- I want to show you **the requirements for the future networks**
- I want to share with you **the directions to go and solutions we can have**

Huawei at a Glance

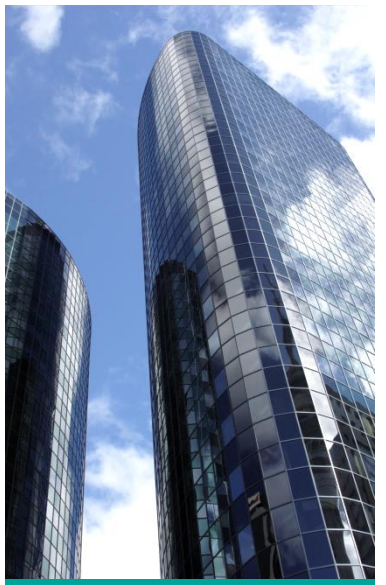
180,000
Employees

80,000
R&D employees

170+
Countries

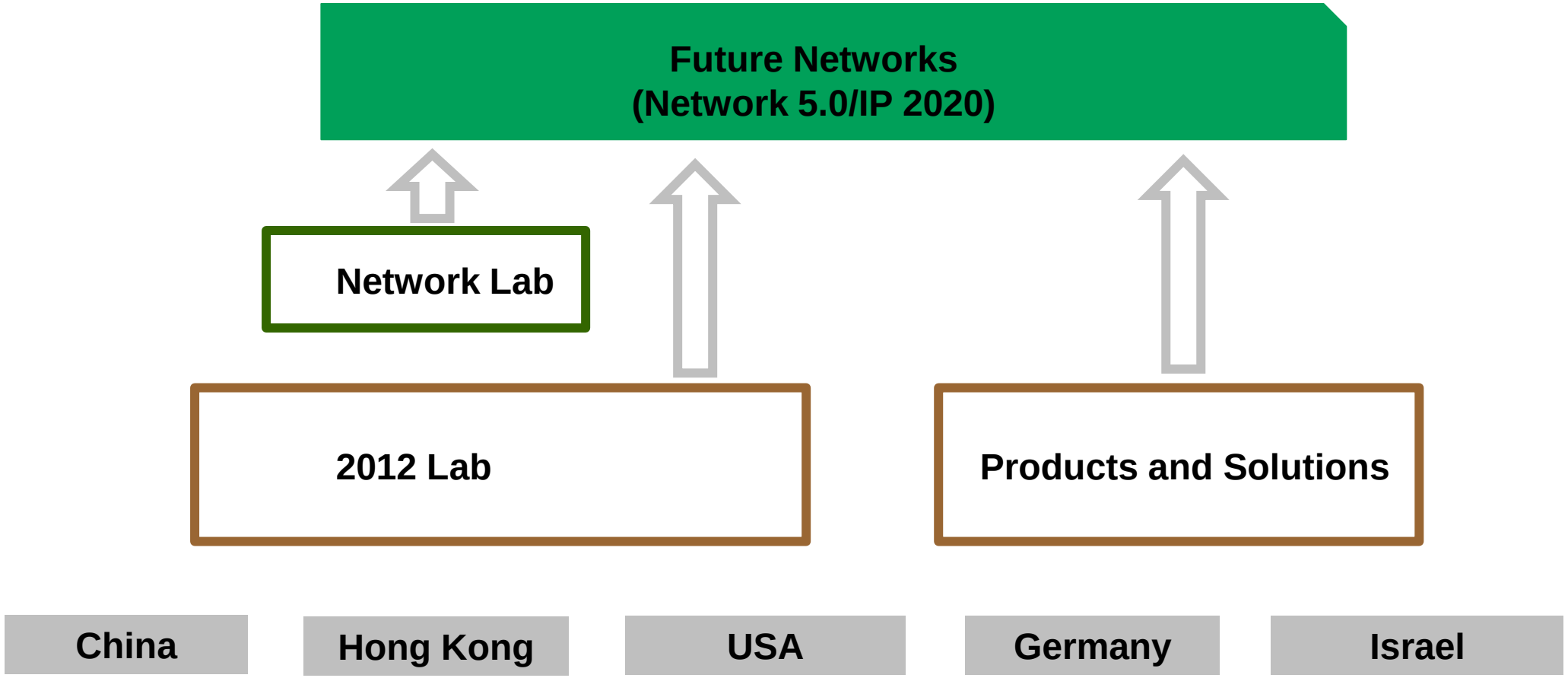
15
R&D institute and centers

No. 72
Interbrand's Top 100 Best Global Brands



No. 129
Fortune Global 500

Future Networks Research in Huawei



Agenda

History Of Packet Switching Technologies

Analyzing the Problems in the Internet

Meeting Requirements for Modern Demands

Huawei’s Strategic Project

5G – A Case Study

IP Has Been So Successful, But Where Did It Come From?

Paul Baran, RAND, US

Inventor Packet Switching

1961

Frank Heart &Team,

BBN IMP Spec

1968

Queen Elizabeth II

Sends her first email.

1976

TCP/IP Standardized

1980

ARPANET ceased

1990

Conceptual — **Experimental** — **Standardization** — **Explosion**

1965

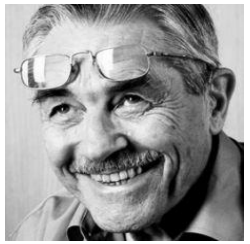
Inventor Packet Switching

Don Davis, NPL, UK

1974

Cyclades at INRIA, France, 1971-1979,

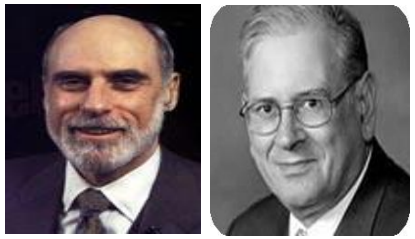
Louis Pouzin



1979

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

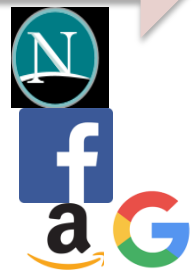
Vinton Cerf and Bob Kahn



1989

WWW, CERN

Tim Berners-Lee



INWG Standards

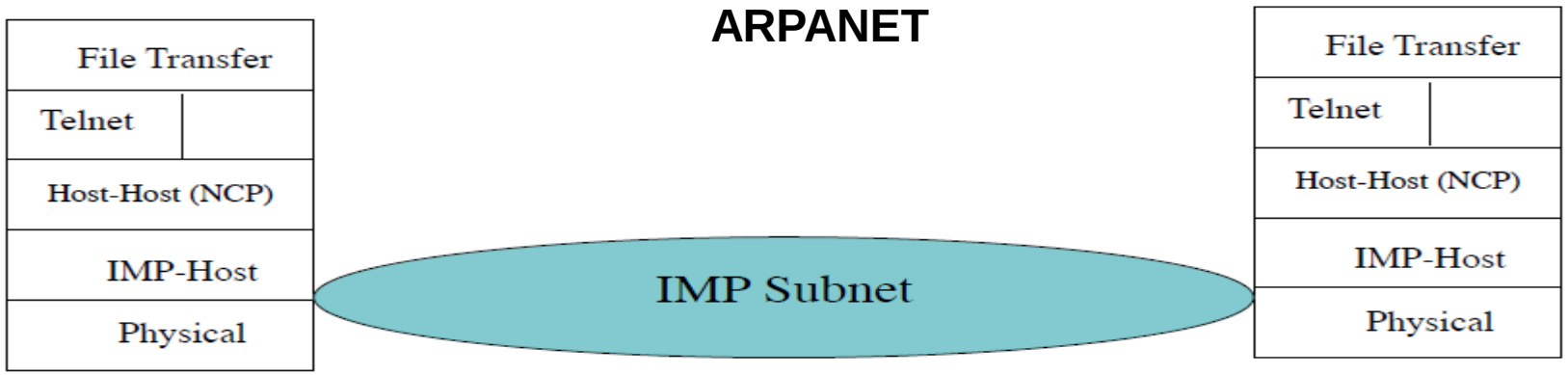
1973 — Host & Process Level protocol — INWG39

1974 — Standard HOST/HOST Protocol — Hubert Zemmermann — INWG61

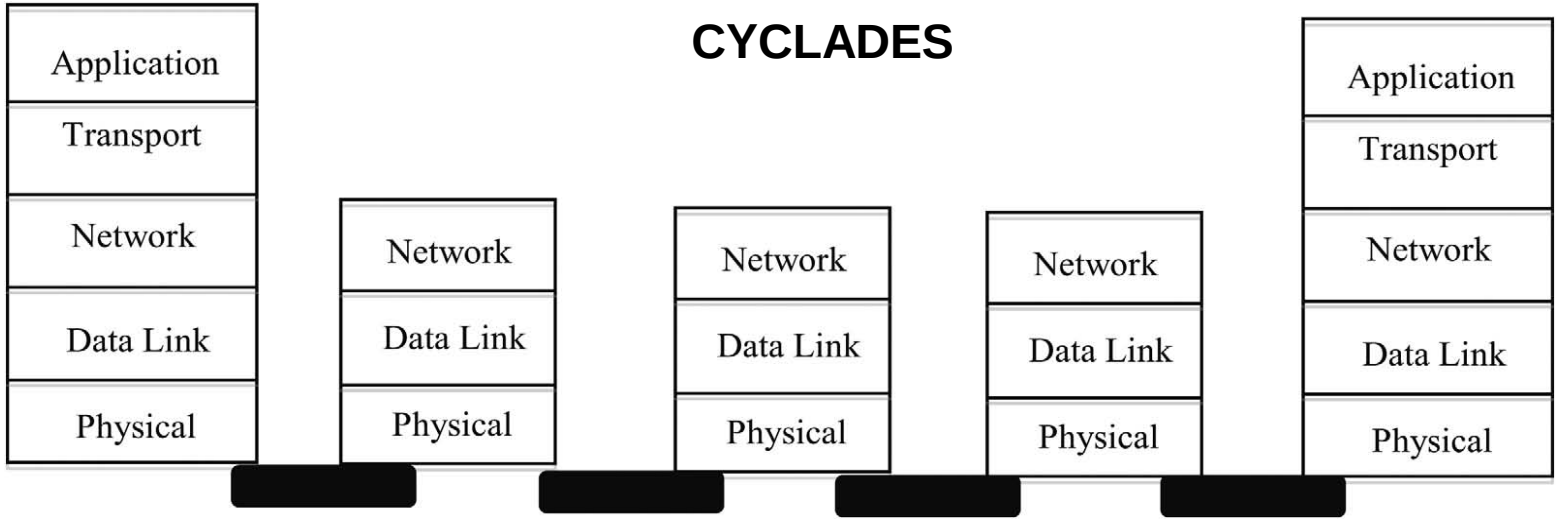
1976 — Cerf (INWG 39 and ARPA), Zimmermann (INWG 61 and Cyclades), Roger Scantlebury (NPL and EIN) — Alex McKenzie — INWG 91

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

ARPANET And CYCLADES Protocol Stacks

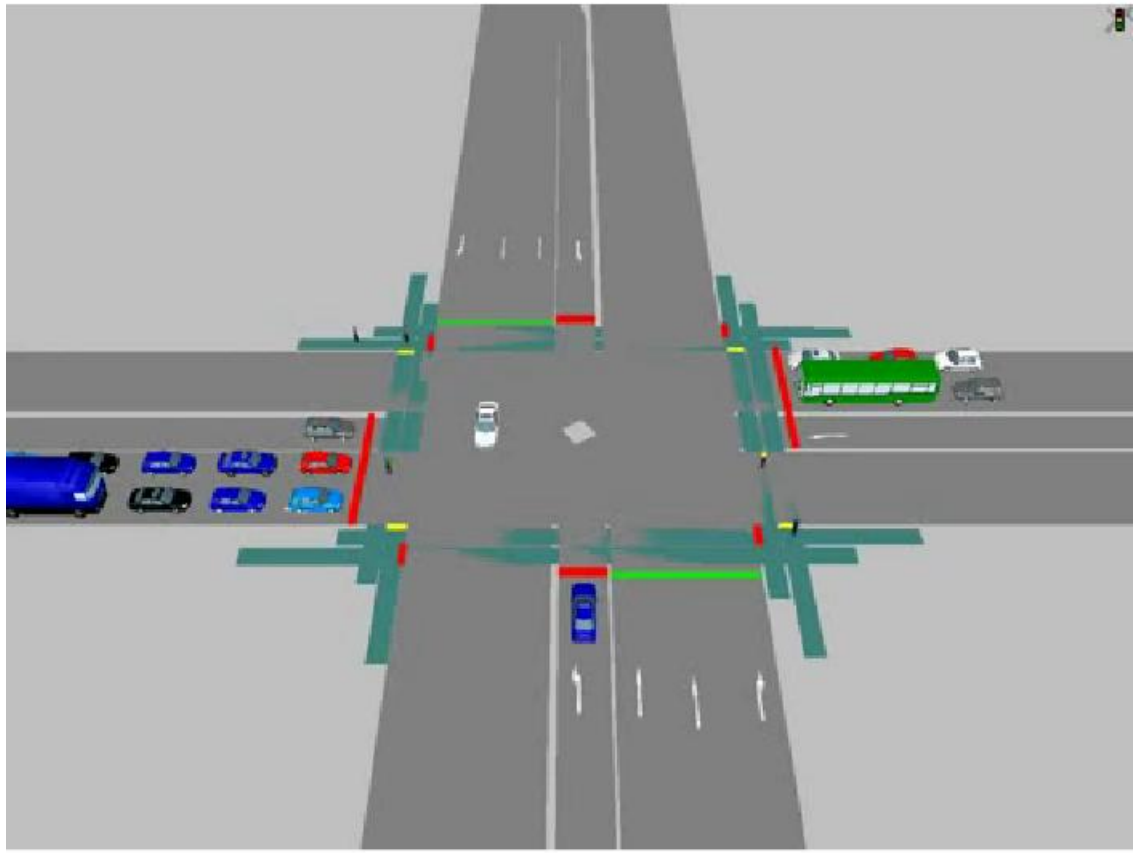


- Maintained byJon Postel
- June 1971.
- "Official Initial Connection Protocol".



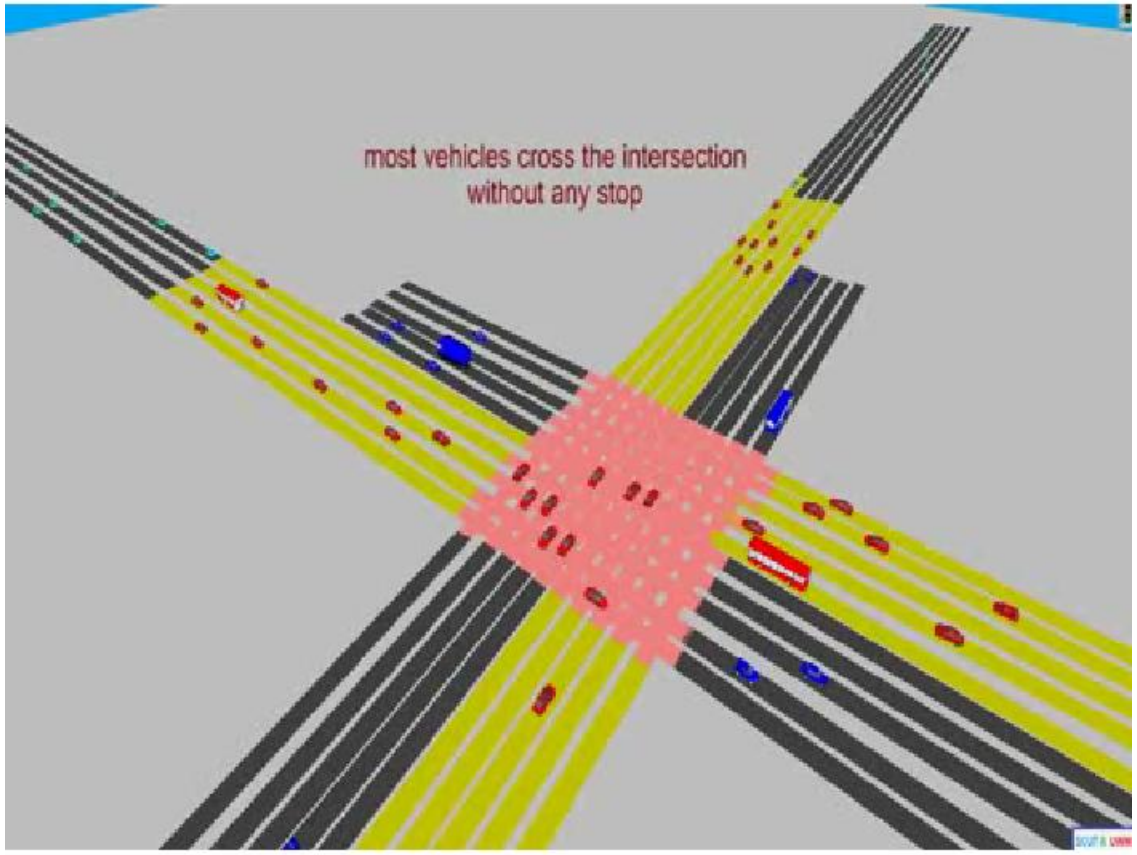
- Developed by Louis Pouzin.
- Unreliable datagram delivery
- ”End-2-End principle

Can the Internet Support Tomorrow's Streets?



Today's Streets

Source: Modification of https://www.youtube.com/watch?v=Yc5i9-mVxfM



Tomorrow's Streets

Source: Modification of https://www.youtube.com/watch?v=sB3vXYr4kL4

Can the Internet Support Tomorrow's Immersive AR/VR?

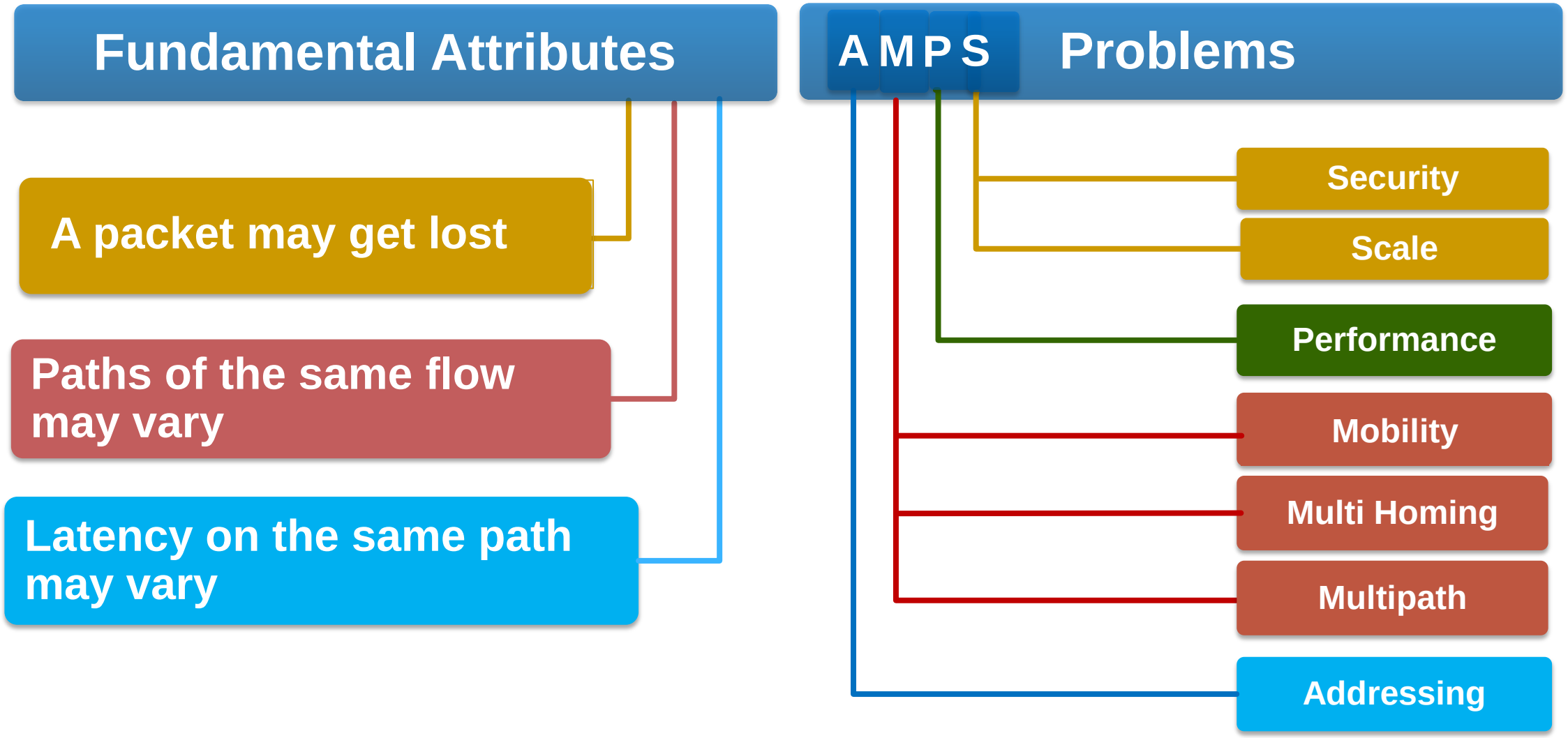
Today's Streaming

Source: Modification of https://www.youtube.com/watch?v=BUPK2tTx0tc

Tomorrow's Streaming

Source: Modification of https://www.youtube.com/watch?v=aThCr0PsyuA

What stops TCP/IP from future applications?



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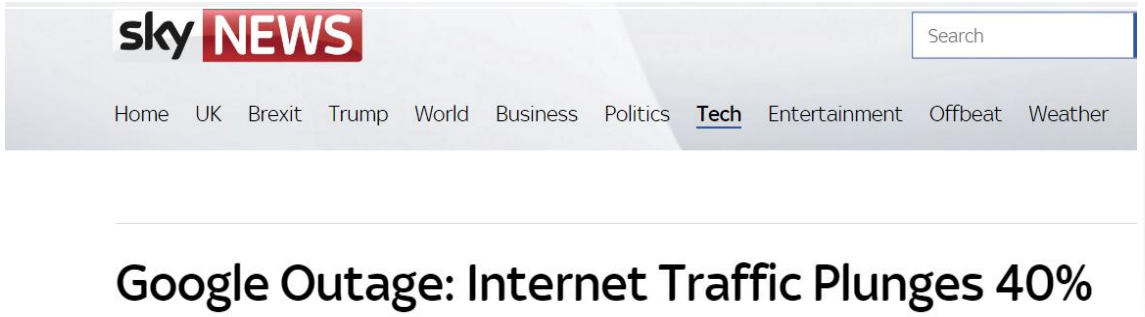
Internet has become Multi-Anchor Centralized

Internet is Increasingly Getting Centralized

Public Cloud Paradox – Handful of established Cloud providers host bulk of our data.
Growing Silos - Through Ecosystems, managed data and APIs

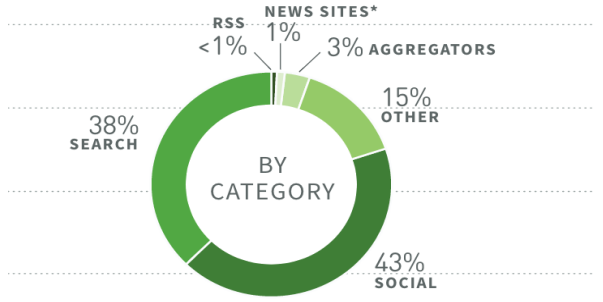
Outages are not Sparsely Scattered

In Aug 2013, a few minutes of Google outage caused 40% of North American traffic outage[1].



Less transparent Information Distribution

Facebook Becomes the Top News Referring Site [2015] :
The algorithm that makes referrals is less transparent [2].



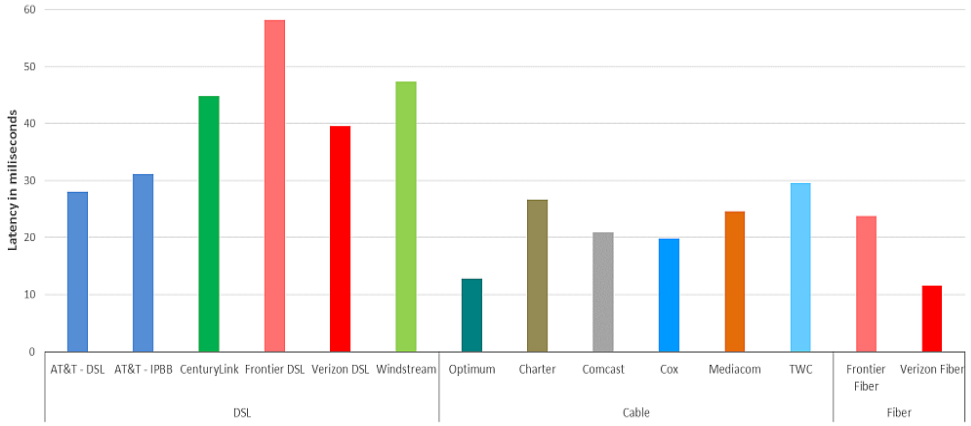
1: [GOOG] http://news.sky.com/story/google-outage-internet-traffic-plunges-40-10437065]
2:[FCB] http://fortune.com/2015/08/18/facebook-google/

Internet has been proud to be Best-Effort, but Best-Effort is, actually, No Effort!

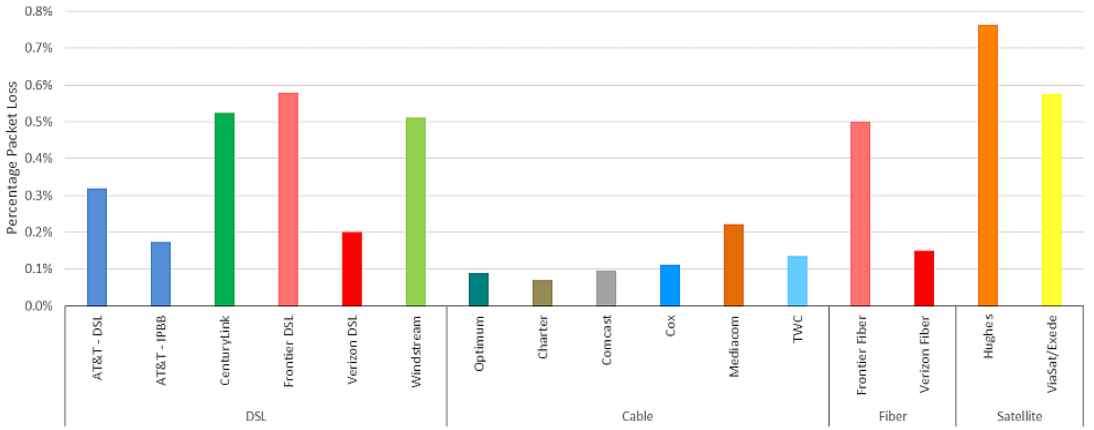
Non-existent Service Level Agreements for Residential Users

Residential Services have no SLA [REPORT][3]

Shared bandwidth with other customers that may degrade some application performance



packet loss = latency exceeds 3 second. Cable: 0.1%



Latency : 12ms-58ms

Effects of Over Subscription upon congestion

- Saving Cost: Divert traffic on already optimally used paths ➔ may cause congestions on existing flow
- Heavy Investments: Fully redundant systems.

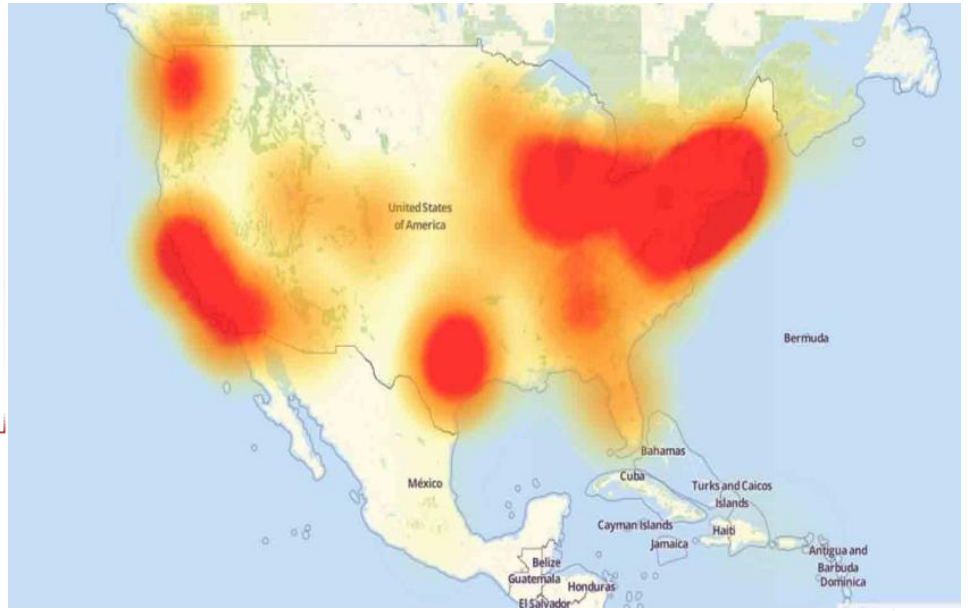
3. [REPORT] https://www.fcc.gov/reports-research/reports/measuring-broadband-america/measuring-fixed-broadband-report-2016

Internet Is Fragile and Vulnerable to Repeated Attacks

Uncontrollable Malware Spread At The Scale Of IoT

21 Oct 2016 DDoS Attack at Dyn,
A provider of DNS services.
Up to 10,000 IoT Devices involved

First [7 AM]
Second [noon]
Third [4 PM][4]



Massive Outages Due To Configuration Errors

Amazon Outage of 28th Feb 2017 (Typo Error)[5]

"Unfortunately, one of the inputs to the command was entered incorrectly and a larger set of servers was removed than intended," the Amazon note states.

Identity Thefts and Data Breaches

Between 2013 and 2016 Billion accounts were hacked – thrice.[6]

Yahoo hit in worst hack ever, 500 million accounts swiped

4:[DDoS] : http://money.cnn.com/2016/10/21/technology/ddos-attack-popular-sites/

5. http://money.cnn.com/2017/03/02/technology/amazon-s3-outage-human-error/

6 http://www.cnbc.com/2017/02/15/yahoo-sends-new-warning-to-customers-about-data-breach.html

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5G – A Case Study

Future Network Has To Be **Open, Smart and Deterministic**

Mobility

- Across different accesses with continuity

Multihoming, Multipath

- Always reachable and discoverable
- Same device different paths per flow basis or load balanced

Addressing

- Reduce overheads over air
- Flexible for different end-point
- Favorable to diverse category of end points

Scale & Security

Path consistency

Economy of path taken
Eg. BGP path distribution

Latency

Predictable & Measurable

Reliability

Next Generation Initiative – A European Consulting Report

Took place between Nov. 2016 and Jan. 2017, with 449 people participated

Top 3 Values

- Internet should ensure citizens' sovereignty over their own data and protect privacy
- Internet should ensure diversity, pluralism, and a right to choose
- Internet should avoid the concentration of data in a few proprietary platforms

Top 3 Technologies

- Personal data spaces
- Artificial Intelligence
- Discovery and identification tools

Next Generation Initiative Consulting Report - Top 3 Technologies

Data Is Personal

Data is everything that identifies an individual: name, telephone number, IP address, date of birth and photographs. The next generation Internet aims to develop technologies to help us ***achieve greater control of our personal data,*** *knowing what is being shared and with whom.*

Artificial Intelligence Will Change The Internet

- Inspired by how the human brain works,
- Mathematical models can learn discrete tasks by analyzing enormous amounts of data.
- Artificial Intelligence will greatly sharpening the behavior of any online service and be core technical enabler of the future Internet.

Discovery And Identification Tools

- Non-proprietary, extensible, future-proof, trustworthy standards for the Internet of Things

Source: https://ec.europa.eu/futurium/en/system/files/ged/ec_ngi_final_report_1.pdf

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Huawei’s Strategic Project
Identity Oriented Networking

5G – A Case Study

IP 2020

- A Huawei research program for the next-generation internet architecture and protocols
- It solves the AMPS problem nicely
- It is aligned with 5G core network architecture and protocols
- It supports 5G, IoT, V2X, and AR/VR
- It is not a clean-slate architecture. It is implementable.
- It cherry-picks all good sides of the IP and builds-in “Open, Smart, and Deterministic” properties

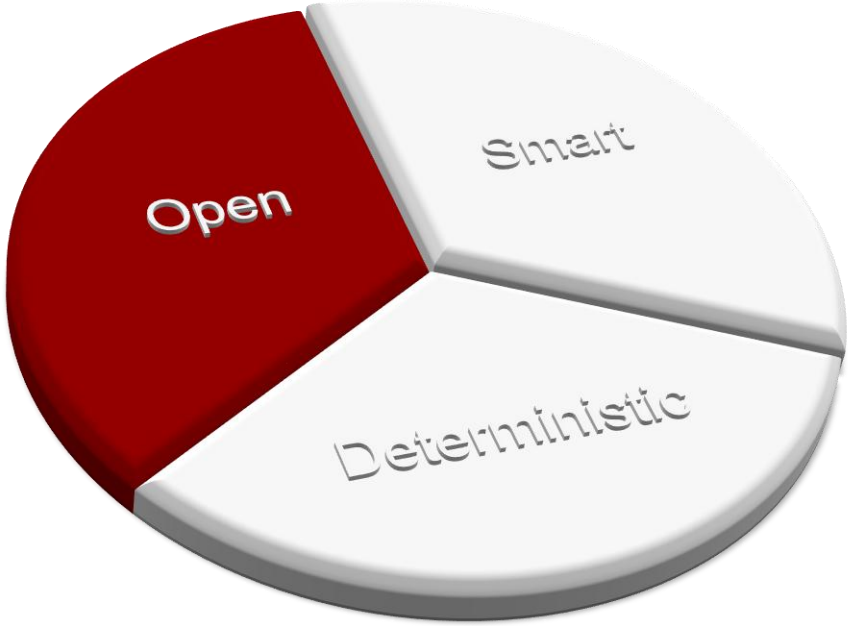
Achieving **Open** Networks

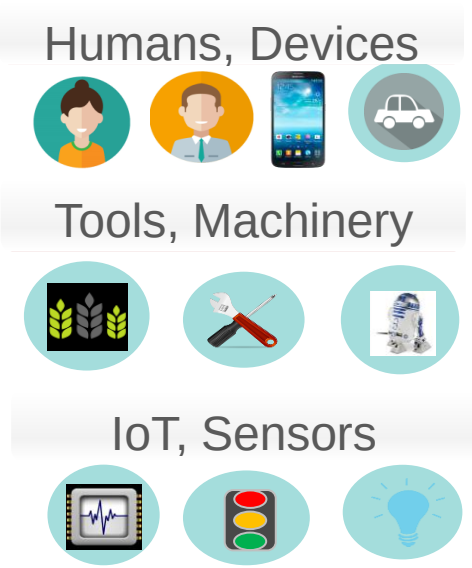
Mobility
- Across different accesses with continuity

Multihoming, Multipath
- Always reachable and discoverable
- Same device different paths per flow basis or load balanced

Addressing
- Reduce overheads over air
- Flexible for different end-point
- Favorable to diverse category of end points

Scale & Security





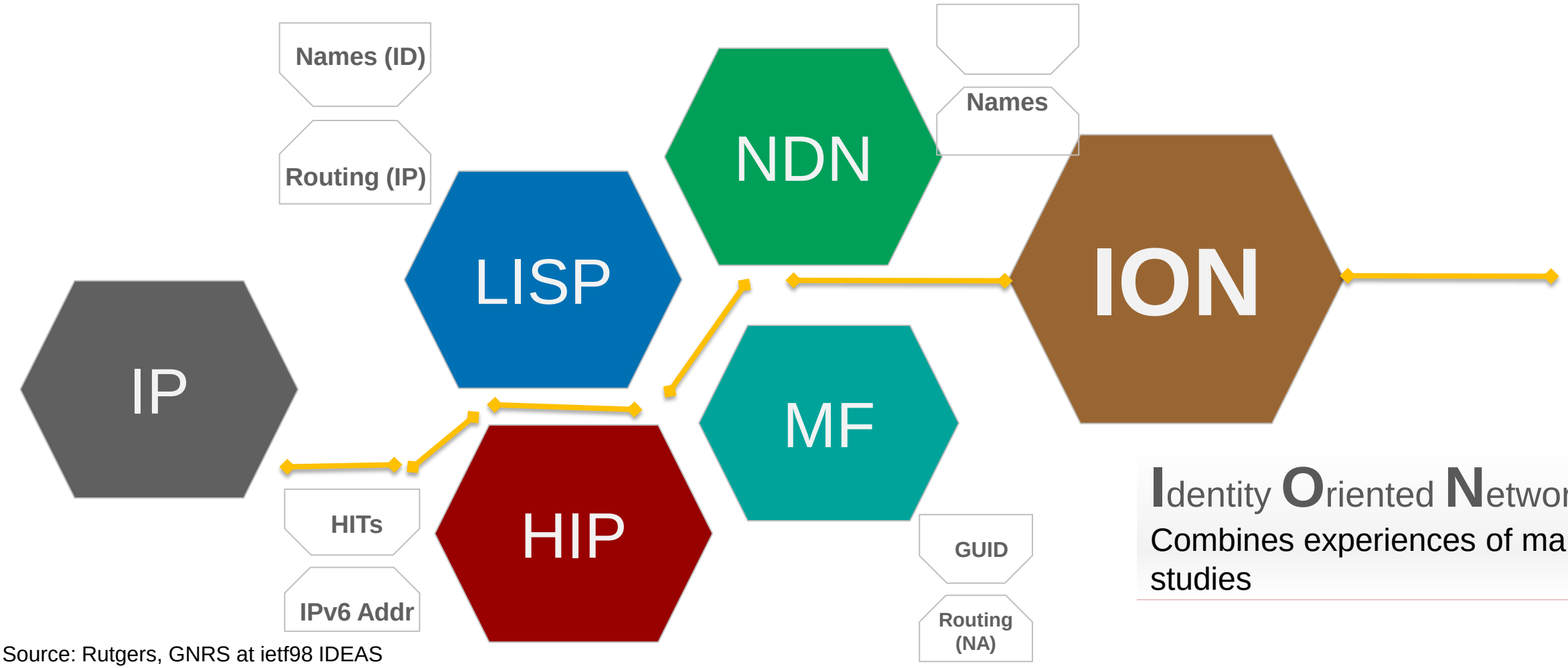
The Tipping Point – Identity Awareness

Identities ARE the communication End points – Inherent to Network Layer

Notion of Identity cross over the threshold from Monolithic Internet.

ID Oriented Networks (ION) And Architectures

Current Internet | **Research and Experiments** | **Industrial Awareness and Adopts**



Identity **O**riented **N**etworks

Combines experiences of many studies

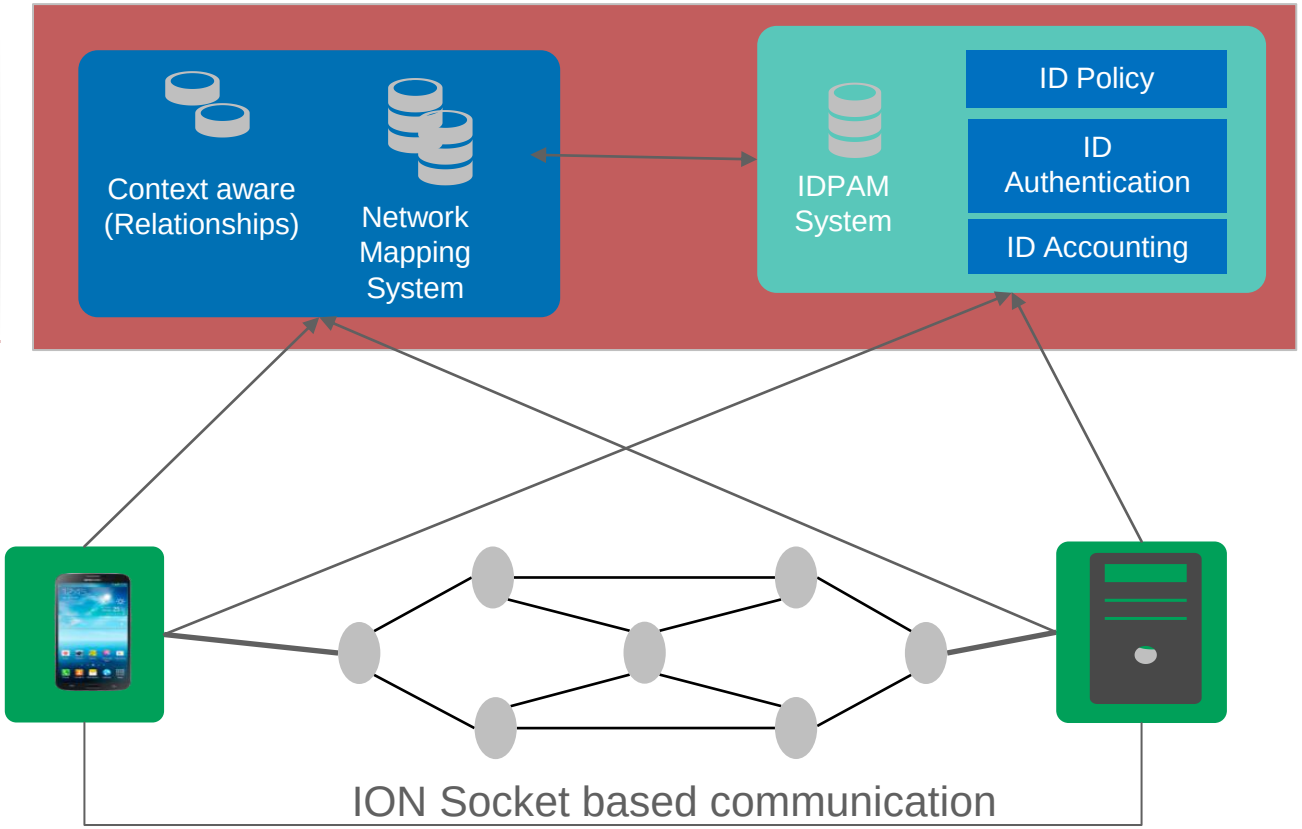
Source: Rutgers, GNRS at ietf98 IDEAS
https://drive.google.com/drive/folders/0BwYx7u1T_20RODdLaWpIdk9feHc?usp=sharing

Complete ION Ecosystem and Work Areas

Control Plane | **Data Plane** | **O/S Socket Interface** | **ION Applications**

Control Plane

Realized via Mapping System
Dynamic, Scalable, ID Aware



Applications with ION

For Example Mobility, Scalability and Social IoT solutions simplified with ION

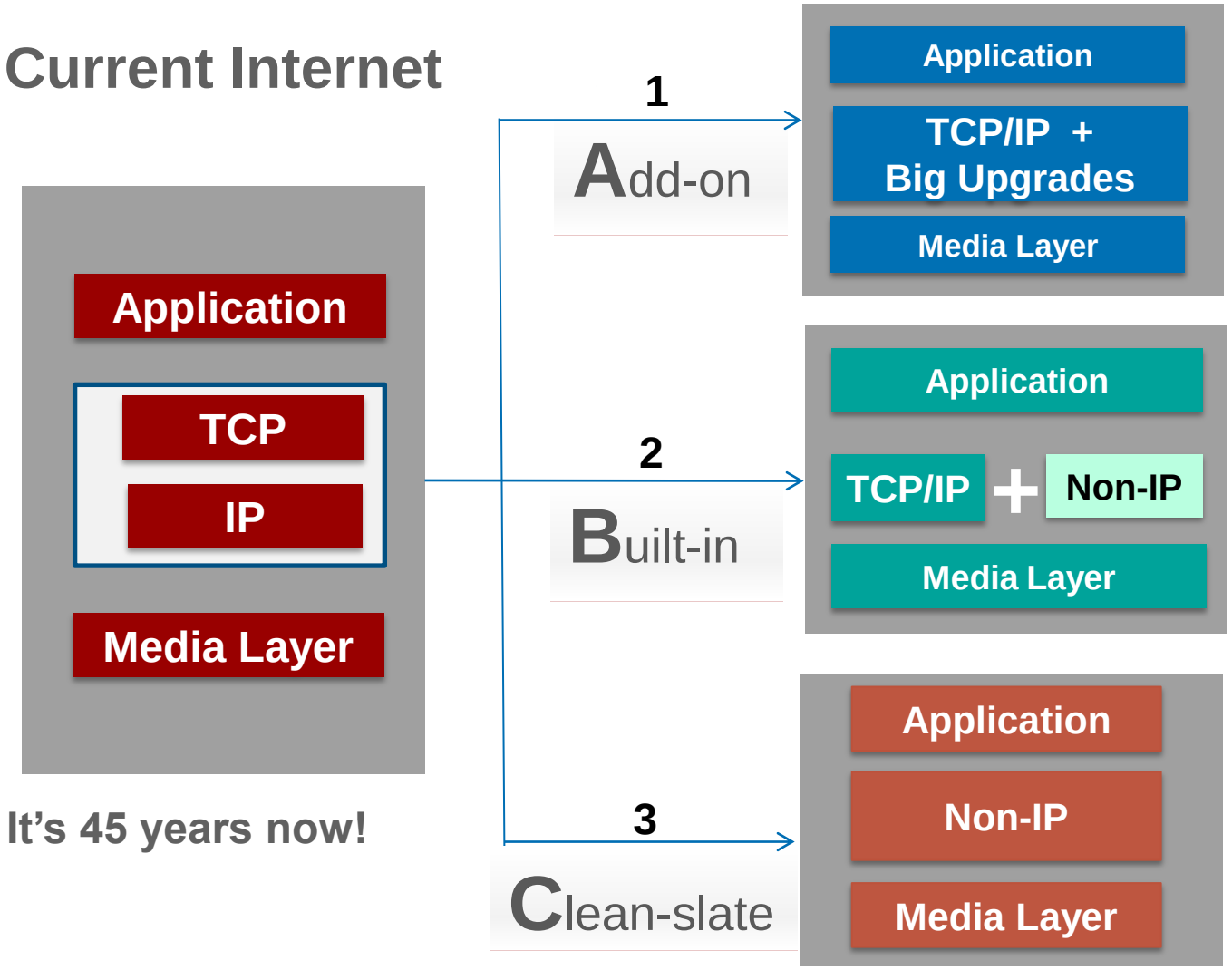
Data plane

Enables packet transmissions in IP core network

Operating System ID socket Interface

End to end ID based connection setup that doesn't depend on IP

Data Plane Evolution



Example: IAB IP Stack Evolution

- QUIC
- MPTCP
- L4S, PLUS

Example: Vendor/US NSF

- IP 2020
- MobilityFirst *
- NDN *, CCN, ICN,
- XIA *

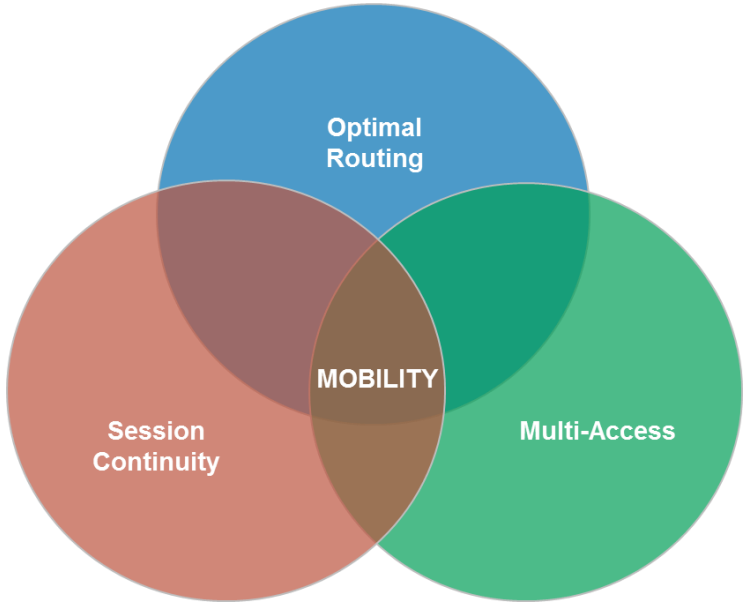
* FIA: Future Internet Architecture

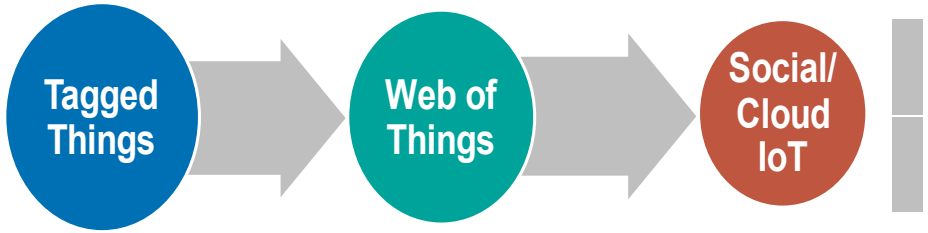
Example: Mostly Academia or history

- ICN, Scion
- RINA
- ATM, Frame Relay

ION Key Scenarios

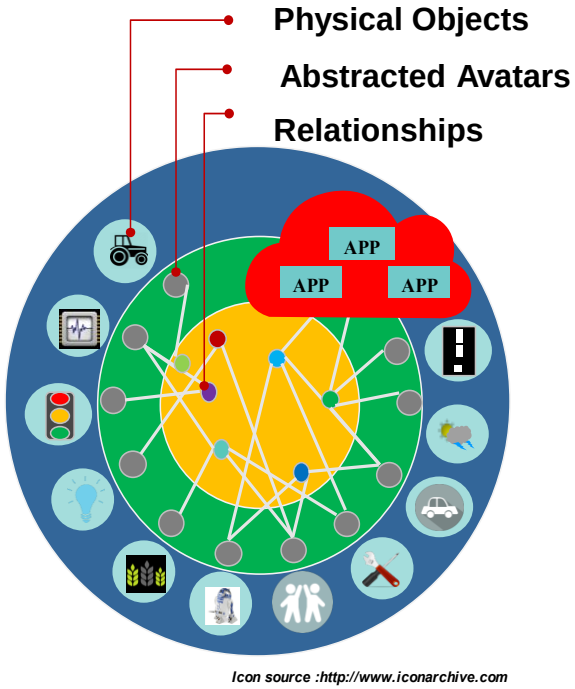
Ubiquitous Mobility | **Massive Scale of Objects** | **Social/Open Relationships**





I. **ID** – to identify things only;

II. **IP** – 1) to find location of a thing; 2) to route there



Icon source :http://www.iconarchive.com

Decoupled Network Address and IDs → **Converged by IP** → **Inter-connected by IP/ID**

ION @ IETF
Chicago, March 2017

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Next-Gen Transport

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Achieving **Determinism** in Networks

Path Consistency

For computations of accurate bandwidth availability

Latency

Immersive media and tactile network applications fail to perform when transmission delays occur

Throughput

High resolution broadcast streaming applications are bandwidth intensive.

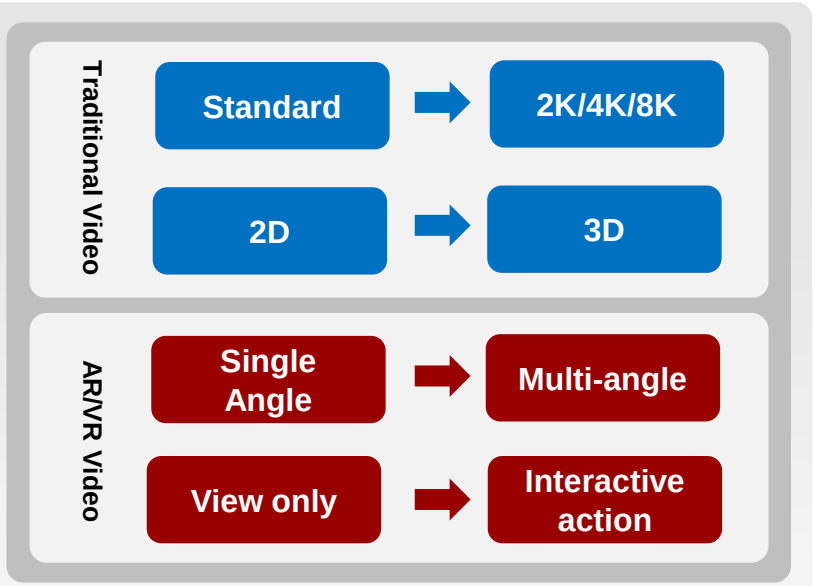
A New Transport

Congestion algorithms to utilize available bandwidth capacity

Use In-network new flow control and scheduling that serves latency and throughput requirements

Corresponding TCP that conveys traffic requirements to Network

Throughput and Latency for Immersive Experience with AR/VR



- The extreme AR/VR user experience needs super high bandwidth and super low latency;
- No industry standard yet for VR classification;
- The Rate and Panorama rate are the stream bit rate for the associated VR, and are estimated based on typical H.264 codec;
- The Bandwidth is calculated as 1.5 time of the associated stream bit rate.

1: MTP < 20ms

- Motion To Photon (MTP) latency is the time needed for a user movement to be fully reflected on a display screen;
- MTP > 20 ms may cause motion sickness or dizziness;
- 20 ms is determined by human body and is rigid latency for VR.

2: Throughput > Gbps

	2D ROI		3D ROI	
	Rate/ Panorama rate	Bandwidth/ Panorama bandwidth	Rate/ Panorama rate	Bandwidth/ Panorama bandwidth
Extreme VR	2.1/8.4 Gbps	3.2/12.8 Gbps	2.5/10 Gbps	**3.8/15.2 Gbps**
Ideal VR	0.5/2 Gbps	0.75/3 Gbps	0.6/2.4 Gbps	0.9/3.6 Gbps
Good VR	17.9/71.6 Mbps	26.9/107.6 Mbps	21.5/86 Mbps	32.3/129.2 Mbps
Basic VR	8.4/33.6 Mbps	12.6/50.4 Mbps	10/40 Mbps	15/60 Mbps

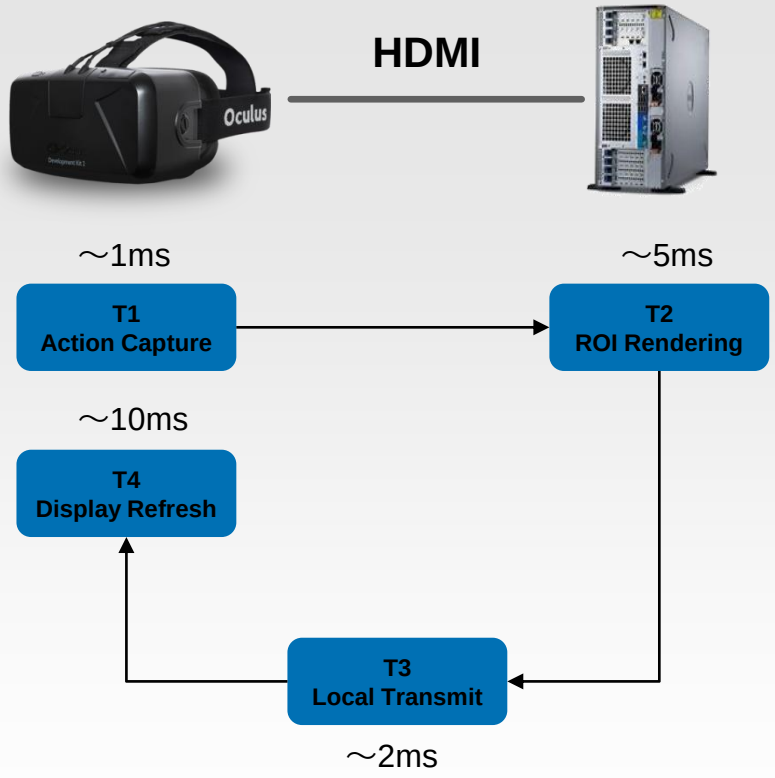
Why High Throughput Matters?

VR Resolution	EQ In TV	KPI
Pre-VR Current: 1K*1K@visual field 2D_30fps_8bit_4K	240P	25 Mbps
Entry-Level VR: 2K*2K@visual field 2D_30fps_8bit_8K	SD	100 Mbps
Advanced VR: 4K*4K@visual field 2D_60fps_10bit_12K	HD	400 Mbps
Ultimate VR: 8K*8K@visual field 3D_120fps_12bit_24K	4K	1000 Mbps* 5 ms **

* It involves new processing technique. Only the data of visual field is transmitted, instead of the panoramic field.
** It involves the one-way time delay, and is recommended for cloud-based VR gaming and strong-interactive VR communication

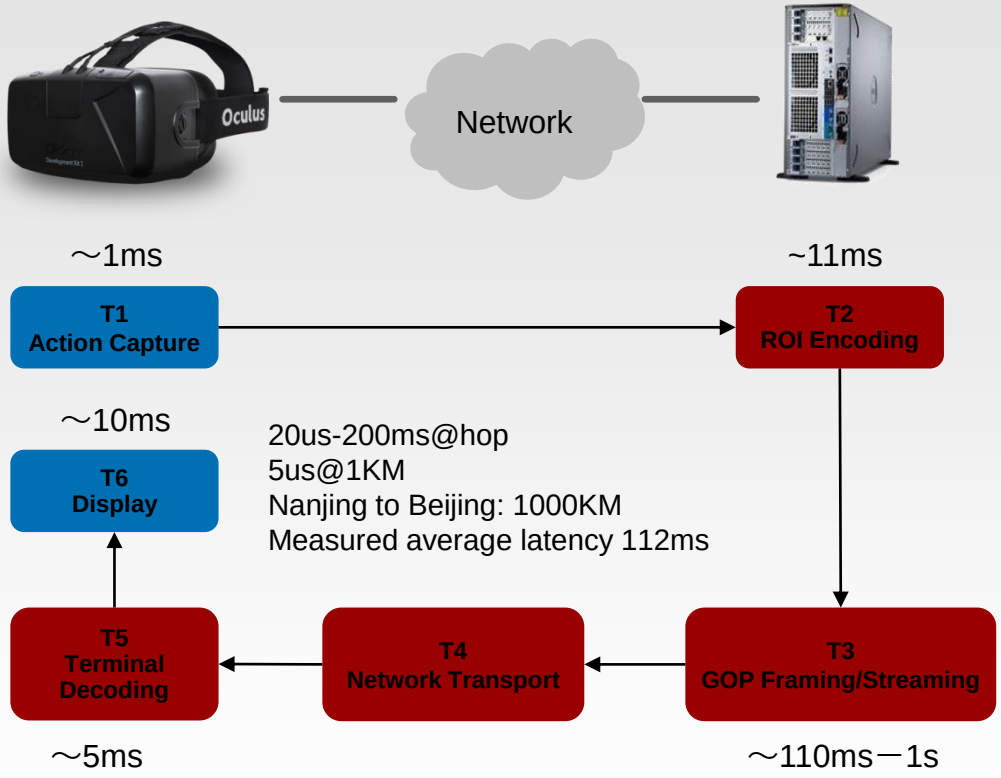
Why Low Latency Matters?

Latency of Localized VR APP: ~18ms



Latency of Localized VR APP <20ms

Total latency of network based VR APP by current technologies: >>20ms



Network based AR/VR APP has 4 more processing than localized APP, Total Latency >> 20ms

Network latency must be < 5-7ms

HW parallel coding

Dynamic refreshing、TimeWap

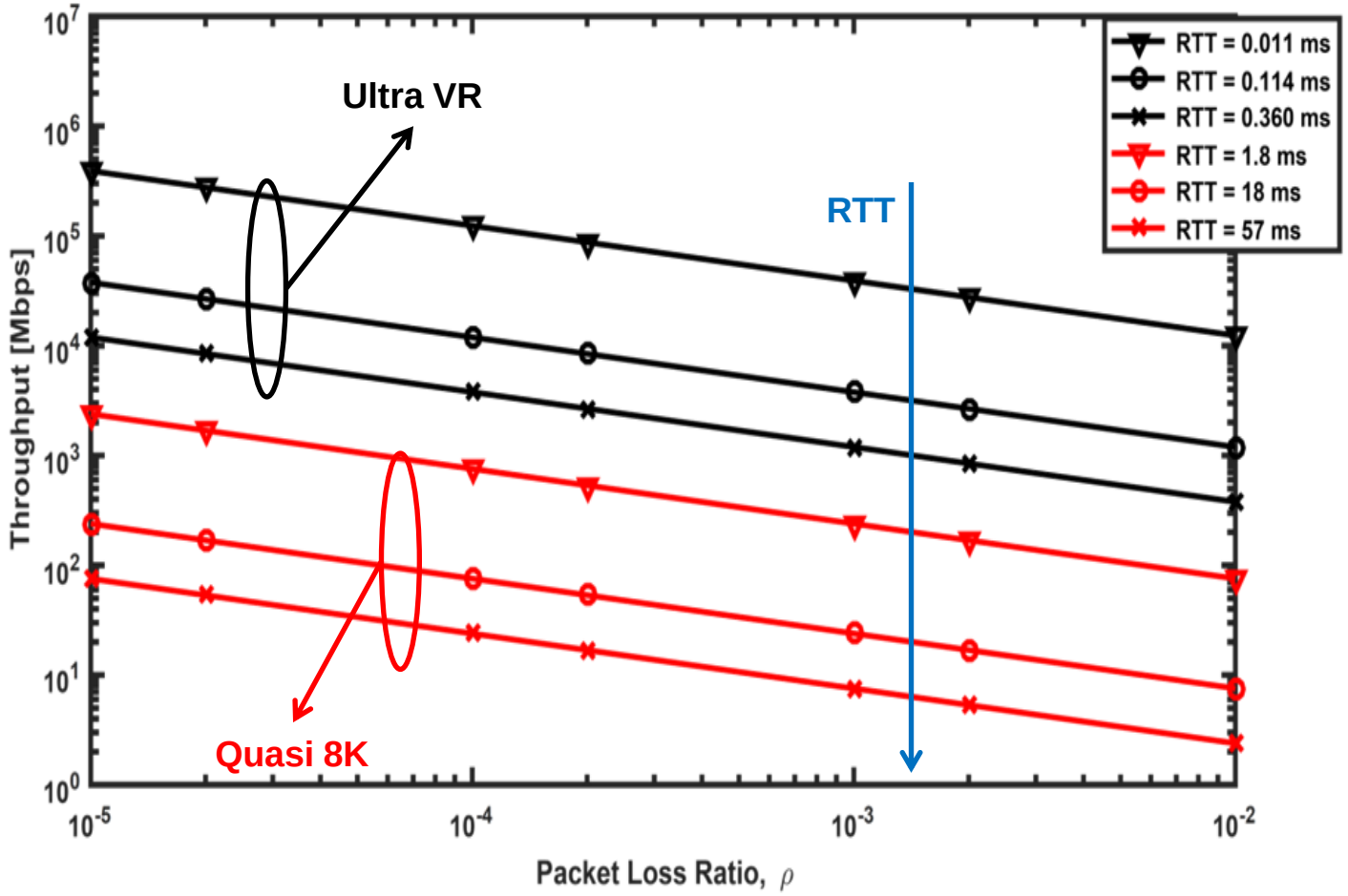
Major optimization for processing time in future VR：

- Action capture ~= 1ms
- Display refreshing ~= 0.01ms（AMOLED screen，dynamic refreshing、TimeWap）
- Server coding ~= 2ms（HW parallel coding）
- Streaming re-order ~= 5ms
- Terminal decoding ~= 5ms
- Network transport ~= 5ms—7ms

Latency in future networks must be about 5~7 ms, considering the technology advances in future

TCP Throughput Law

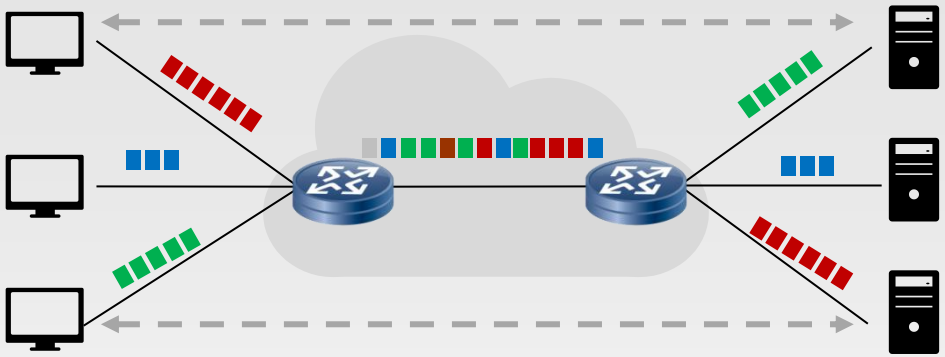
Relationship between Throughput, Packet Loss and Delay



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

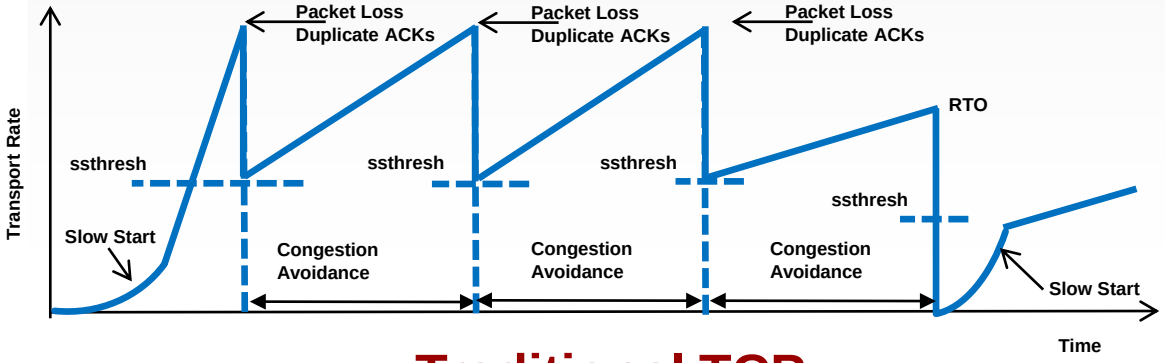
- The TCP throughput is inversely proportional to its packet loss ratio and round-trip time delay.
- Example: For throughput 12 gbps and packet loss ratio 1/10,000, the end-to-end delay is 0.114 ms.

Deterministic TCP (DTCP)

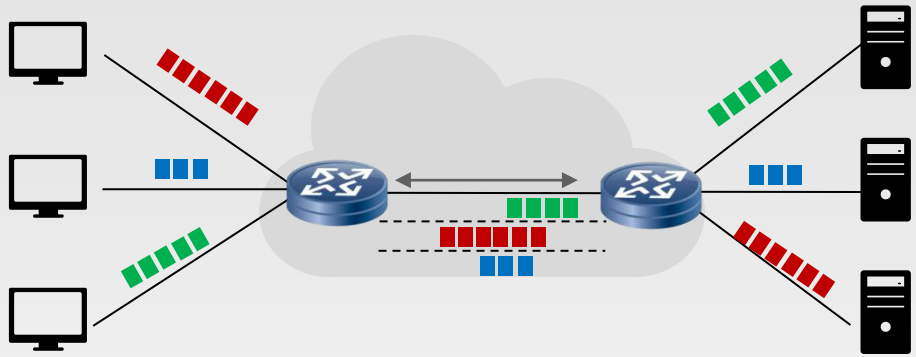


TCP Requirement:
- Avoid congestion
- Higher bandwidth utilization

Method:
- Sliding window mechanism



Traditional TCP

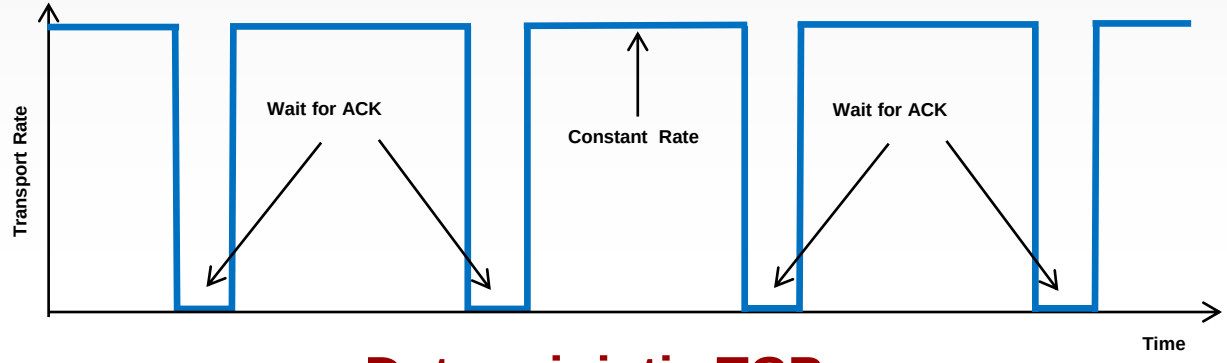


Flow control for DTCP：
- Leaky bucket：rate limit
- Token bucket：allow burs

Retransmission mechanism:
- FIFO

DTCP：
- Signaling by TCP
- Provide guaranteed network resource

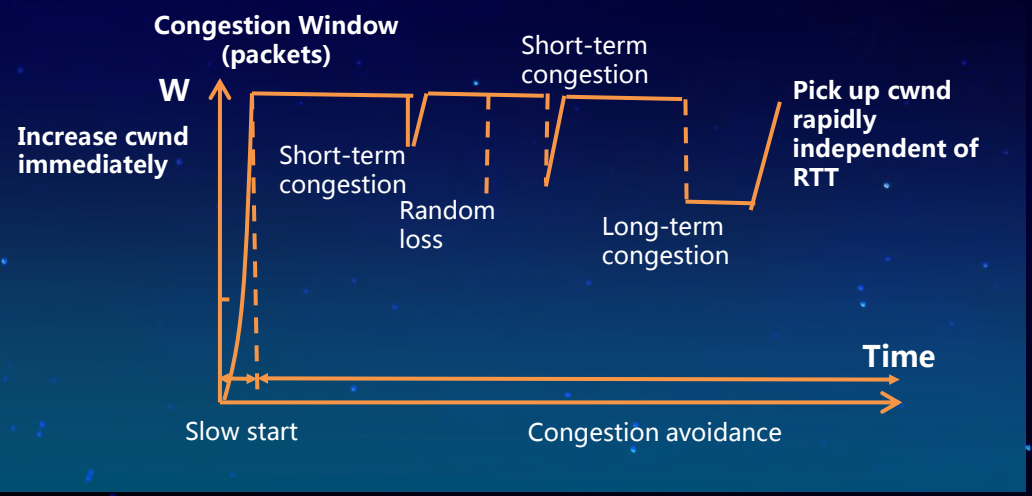
Transport benefits：
- TCP does not need to use different congestion avoid mechanism to reach target rate
- Higher bandwidth utilization due to no packet loss signaling



Deterministic TCP

Optimized Transport for High Throughput

High throughput transport unrelated with RTT



Throughput Formula unrelated with RTT

Throughput=f(p,BW)

wherein：

p: Packet Loss Rate

BW：BandWidth

- **Key idea** : Change the new design of transport layer from being based on from non-transparent to transparent(including measurement and ECN+)
- **Key technologies：**

1. RTT unrelated: On start-up, the cwnd is increased to objective throughput within one step according to the service requirement, which can reduce the quick-start time of video. On congestion recovery, the cwnd recovers rapidly independently of RTT.

2. Reduce the impact of packet loss: Distinguishing between random packet loss / short-term congestion and long congestion. Implement a new CC to reduce the impact of random packet loss and loss of short-term congestion.

Agenda

History Of Packet Switching Technologies

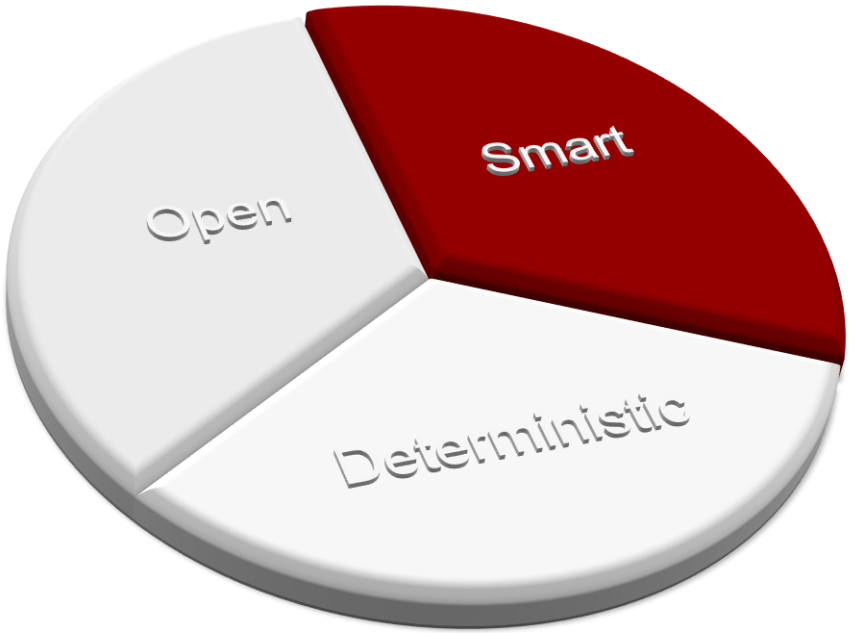
Analyzing the Problems in the Internet

Meeting Requirements for Modern Demands

Huawei’s Strategic Project
Intelligence Defined Networking

5G – A Case Study

Achieving **Intelligence** in Networks



- **Self-Configuration**
- **Self-Organization**
- **Self-Optimization**
- **Self-Learning**
- **Self-Diagnosis**

Intelligence In Networks

Learns through past data about traffic patterns in the system

Makes decisions based on behavior learnt over time

Proactive operations in network systems as against reactive

Cognitive

Pertaining to mental process of memory, perception, judgement, reasoning and learning.

Learn

Network nodes do not have to be provisioned – neither templates, nor API

Predict

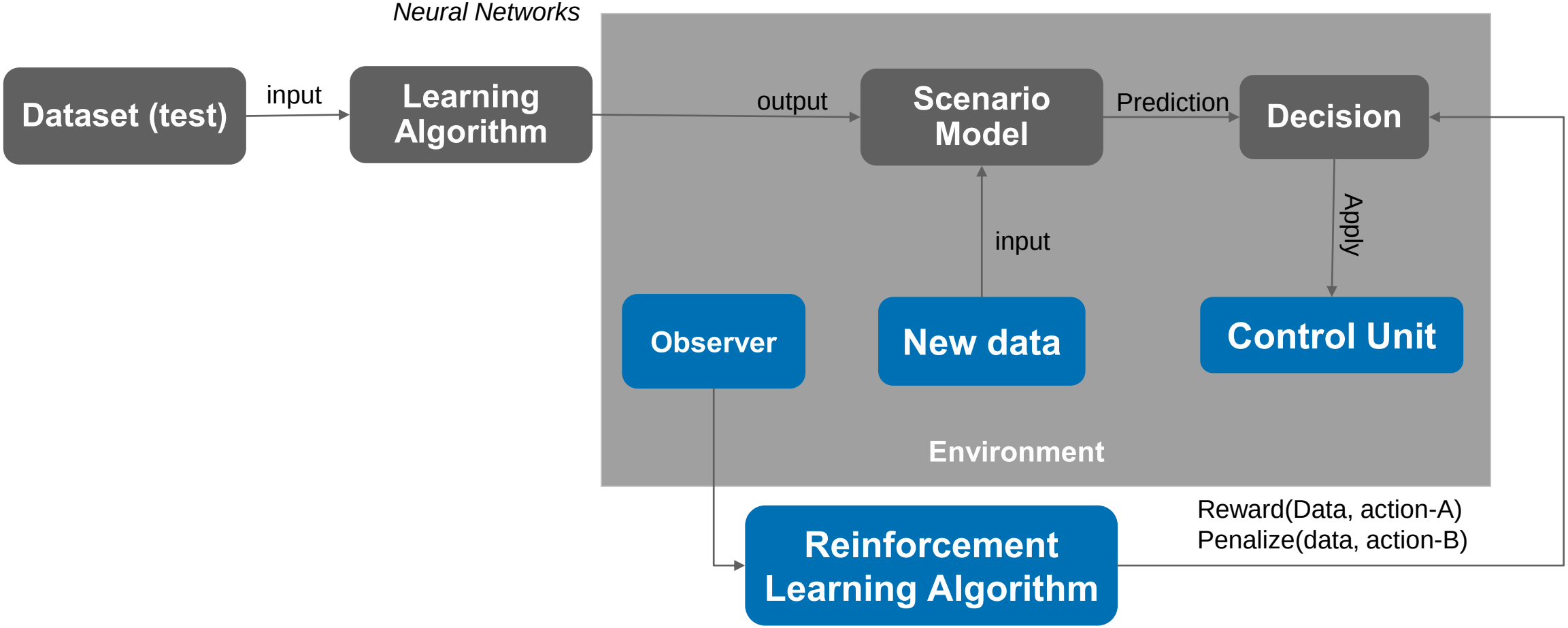
Traffic type, durations and resource requirements of flows
Take measures to prevent outages from happening

Monitor

Replace existing automation based Diagnosis to learning diagnosis cycle.

A Generalized Machine Learning Loop

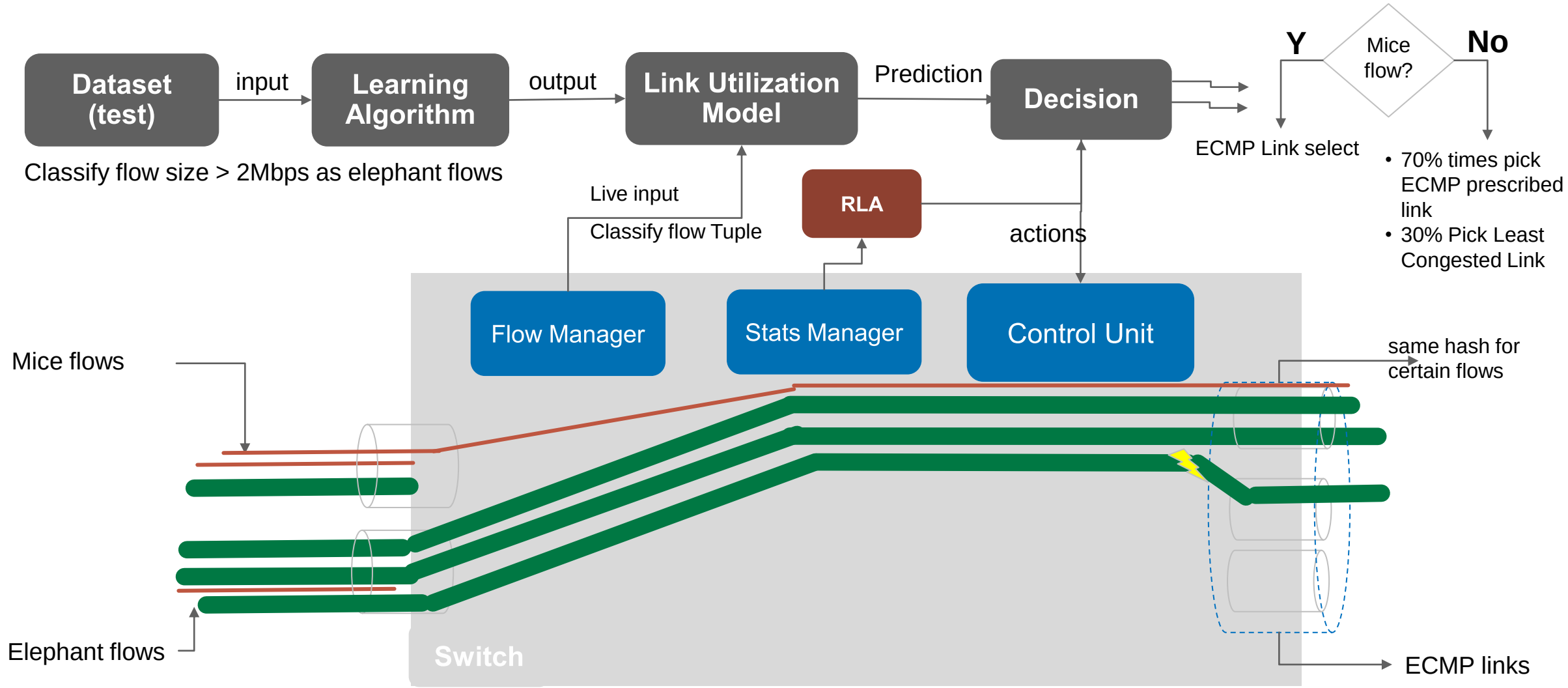
Examples *Regression*
Neural Networks



An Example: ECMP Based Link Utilization Problem in a Switch

- **Massive Scale DCs use fixed spine-leaf topology**
- **ECMP distributes traffic across multiple paths**
- **ECMP uses Hash computation to balance similar flows over multiple links**
- **However, the flows are not evenly balanced**
  - Low-bandwidth (Mice) flows: Majority of flows are short-lived and latency sensitive.
    - Example: Web, chat applications
  - High-bandwidth (Elephant) flows consume majority bandwidth and are long-lived.
    - Example Storage-intensive big-data, data-replication and backup applications
- **Problem**
  - Variance in the amount of bandwidth used between long-lived vs short-lived flows does not ensure that traffic is balanced across all the links.
  - Increase in Mean-time-to completion for mice flows
  - Reduced data-rate for elephant flows due to congestion control

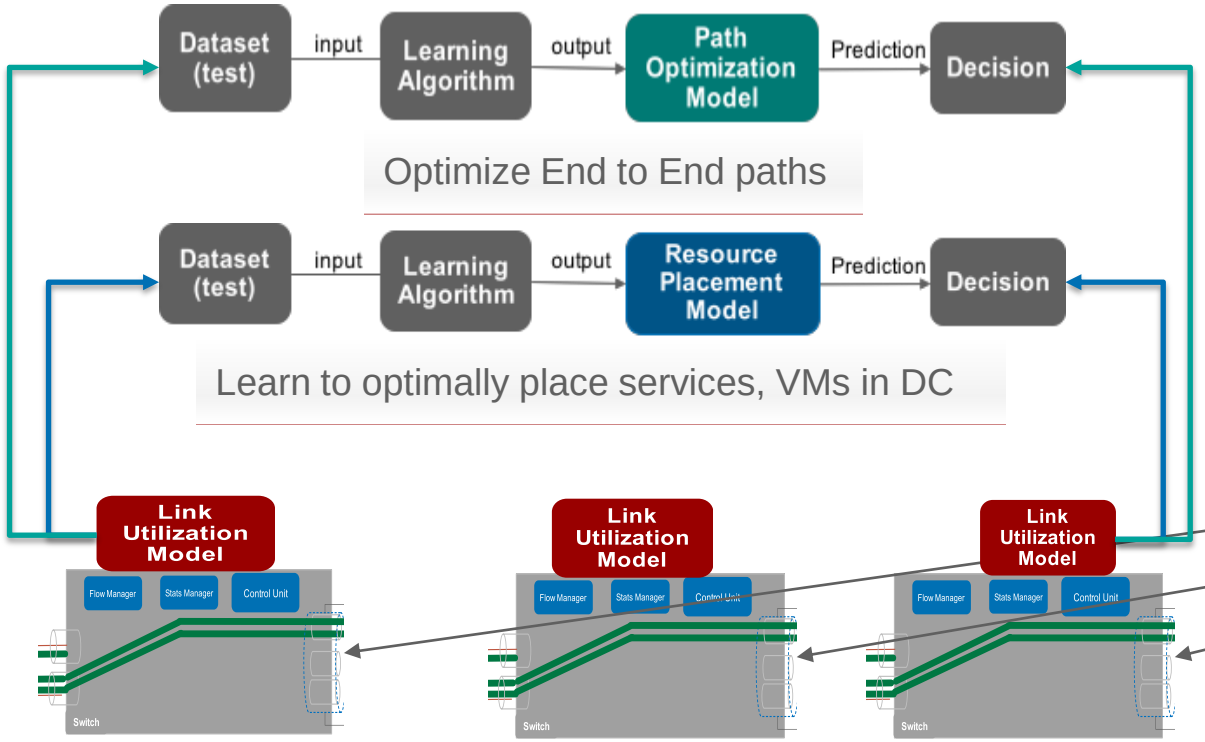
Machine Learning for ECMP Link Utilization in a Switch

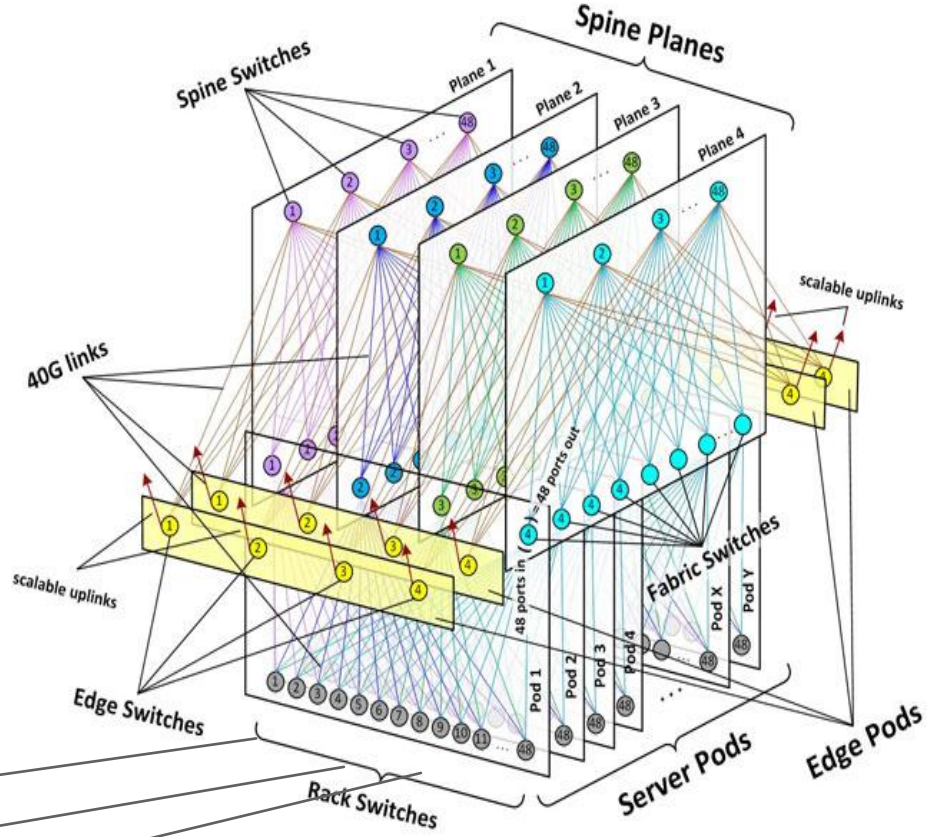


RLA – Reinforcement Learning Algorithm

Intelligence Driven Networking – DC Scenarios with Global Scope

- Extend to wider scoped learning - Global models across multiple switches
- Different Learning models for different scenarios together





Src: Facebook data center

Agenda

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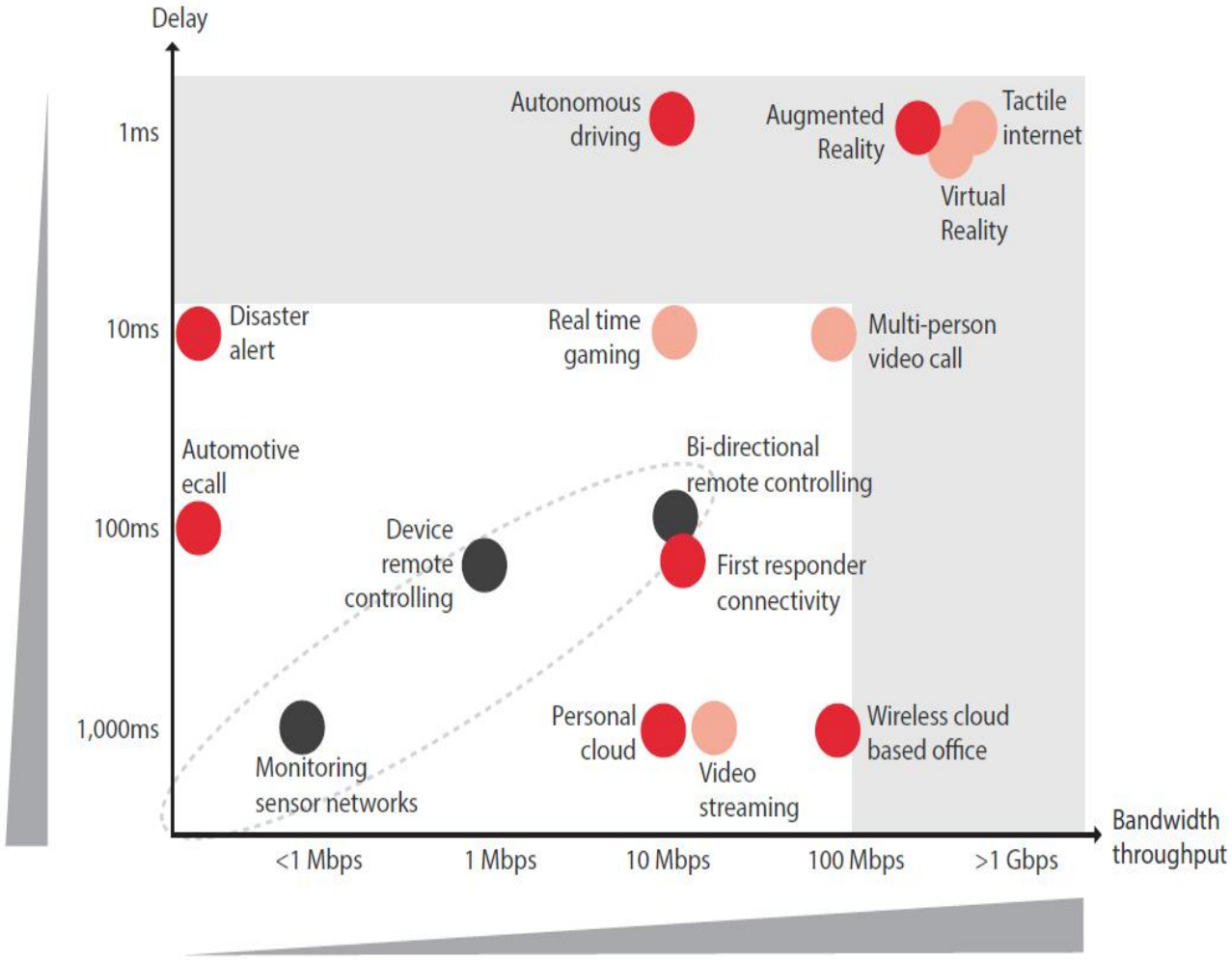
A Case Study on Mobile Networks – Potential Of 5G



Virtual Reality/Augmented Reality/Immersive or Tactile Internet
Manufacturing, Medicine, Wearables

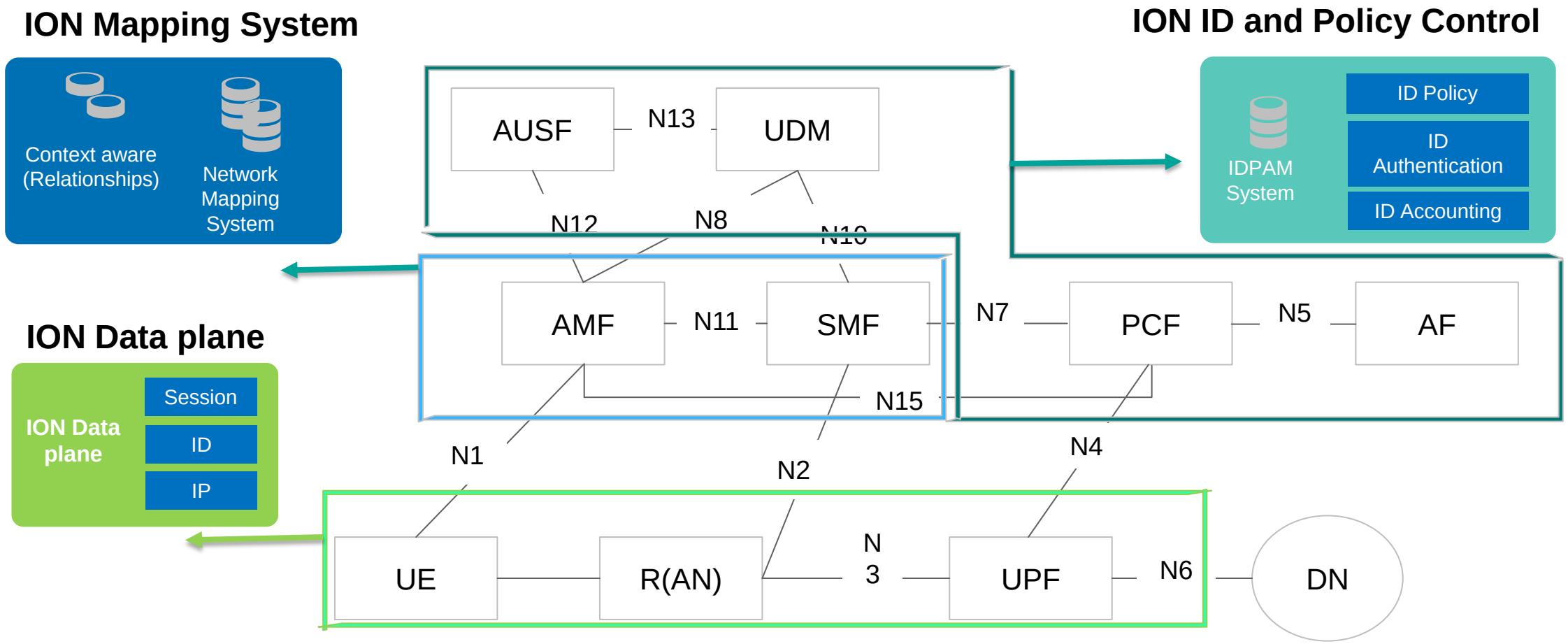
Autonomous driving/Connected cars
Driven at higher speeds, Close proximity, reduced accident risks

Wireless cloud-based office
Multi-person video conferencing at much lower latency than today

Machine-to-machine connectivity (M2M)
Smart homes, Connected cities, Vehicle telemetry

Source: GSMA

Reference 5G Architecture IP2020 & 5G - A Case Study



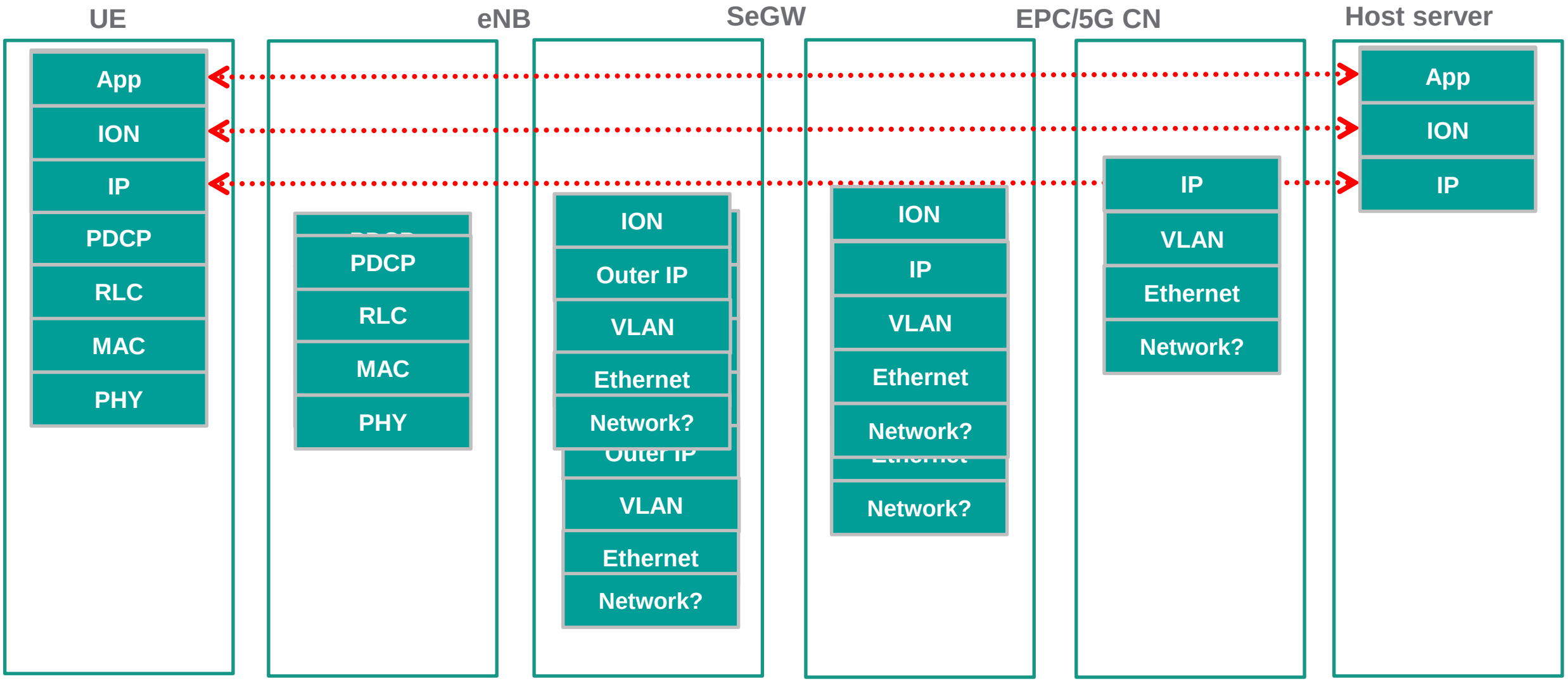
AUSF. Authentication Server Function
AMF. Access and Mobility Management Function
SMF. Session Management Function

AF Application Function
DN Data Network
UDM Unified Data Management

PCF Policy Control Function
UPF User Plane Function

Source : TS-23.501 V 0.3.1 March 2017

Protocol Stack Reduction and Efficiency with IP2020



Summary

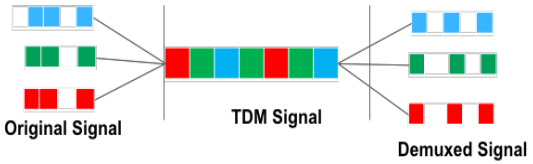
Network 5.0

Analog

1.0

TDM

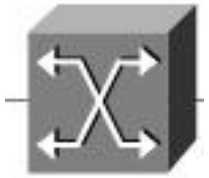
2.0



Time-divided multiplexing
Multiplex Information into single channel

ATM

3.0



Cell multiplexing
Fixed-size cells
Connection oriented path setup.

IP

4.0

Statistical multiplexing
Connectionless
Variable-length frame

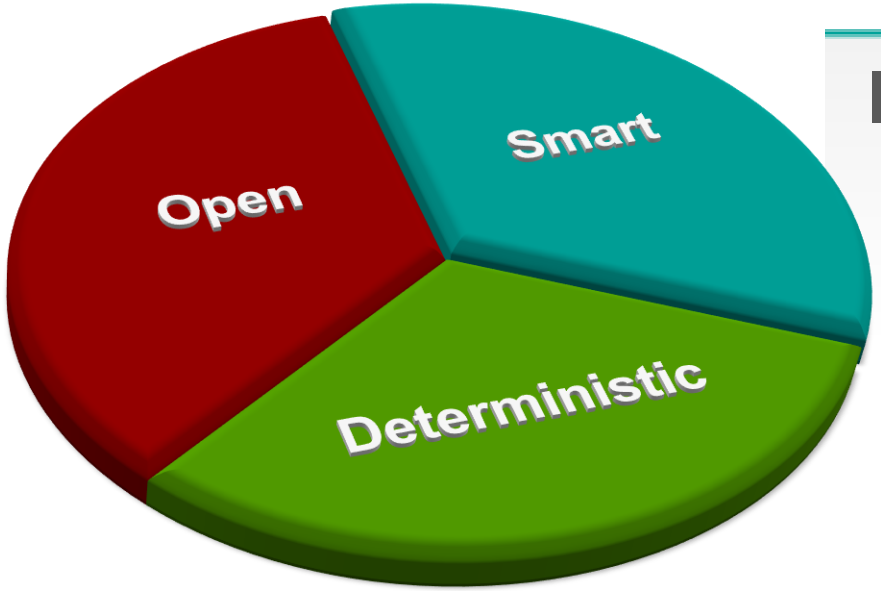
what's next?

5.0

Circuit Switching	Multiplex Switching	Cell Switching	Packet Switching	

Summing Up - IP2020 Delivers Next Generation Networks

Identity **O**riented **N**etworking
(ION)



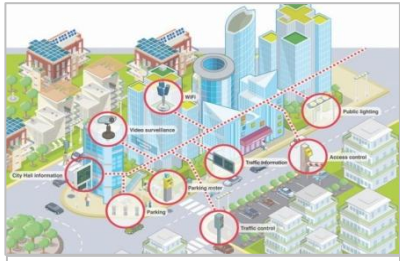
Intelligence **D**riven **N**etworks
(IDN)

Wearable WSN

Smart Home

Next-**G**en **T**ransport
(NG-T)

Autonomous Driving



Smart Cities

Building Next-Generation Networks

Five Criteria To Deliver Data for Future Applications

THROUGHPUT

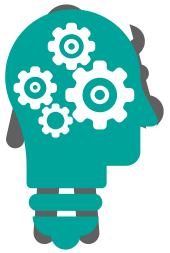
Higher the Better

LATENCY

Shorter the Better

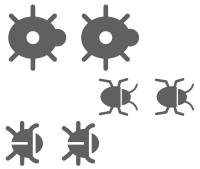
MOBILITY

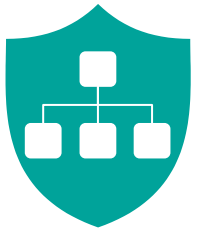
Continuous

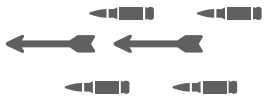


Intelligent

Smarter the Better



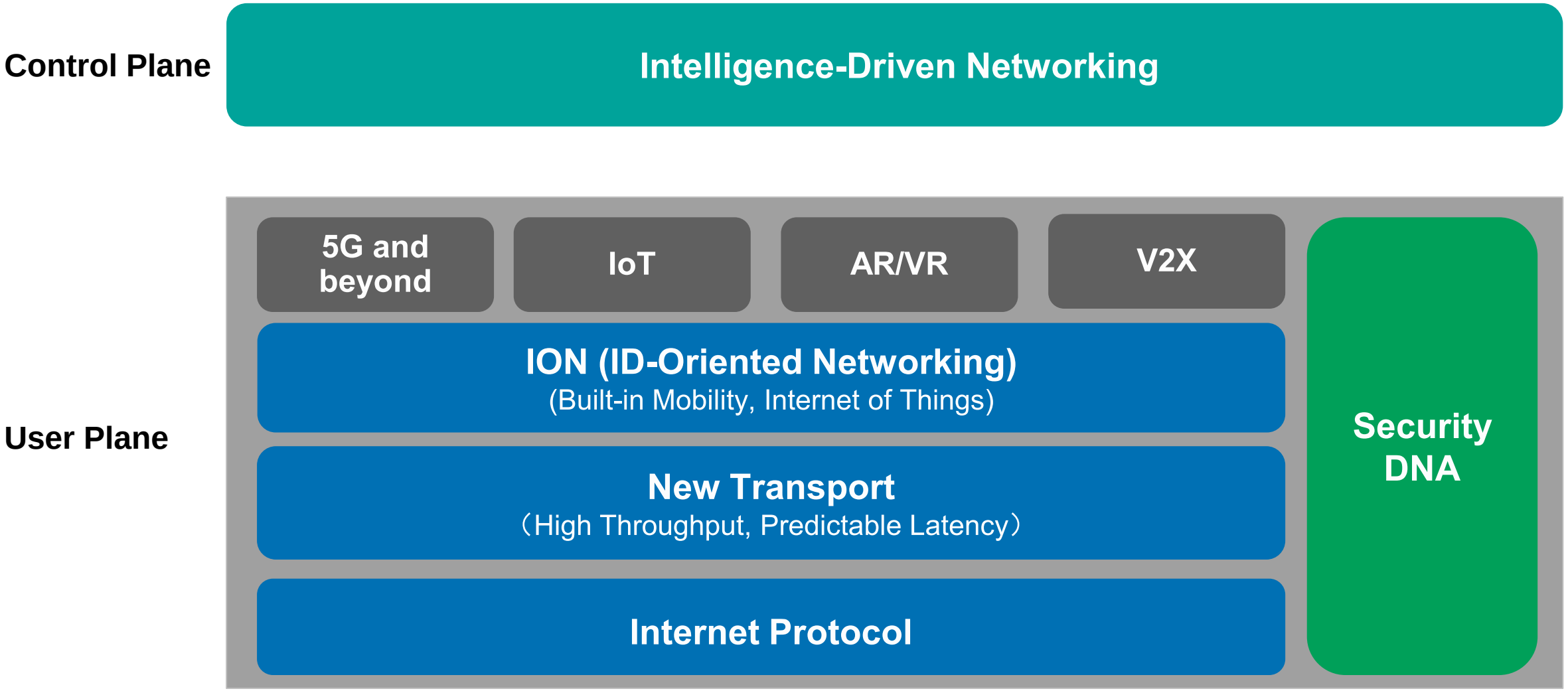




SECURITY

Stronger the Healthier

IP 2020 Protocol Stack



Thank you

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