Challenges for IP 2020

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Agenda

- **Rethinking Network protocols**
  - New use cases and scenarios
- **Challenges in**
  - Network Addressability
  - Transport
  - Security
  - Network operations

New Use Cases And Scenarios - Rethinking about IP Networks

New Applications

- **Connectivity as a strategic engine**

Entertainment | eCommerce | B2B/B2C | Disaster Resp. | Healthcare | Industry | Automobiles

New Technologies

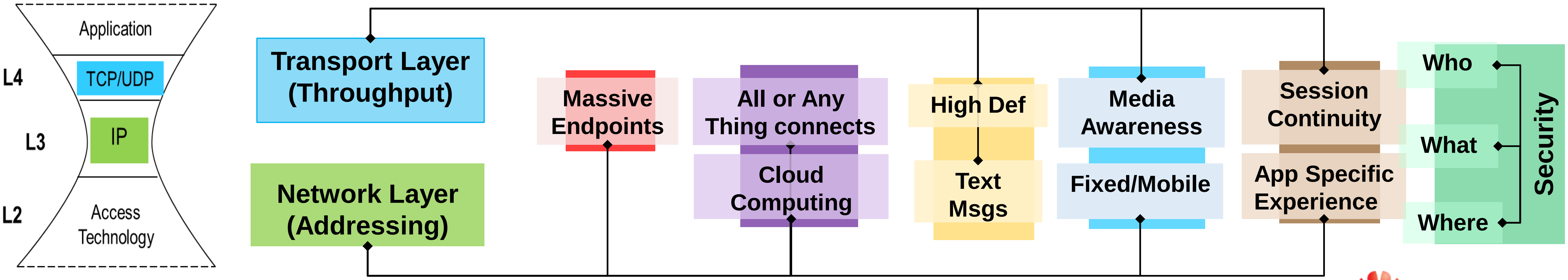
- **Better devices: more personal, more connected**

Communicating Robots, Sensors | **Mobility in communications** | **Streaming Immersive multi-media** | **Tactile Networks**

New Demands

Scale | **Always -On** | **Pervasive bandwidth** | **Determinable Latency** | **Non-Disruptive** | **Trusted**

- **What about our networks?**



Future Networks, America Research Center, US

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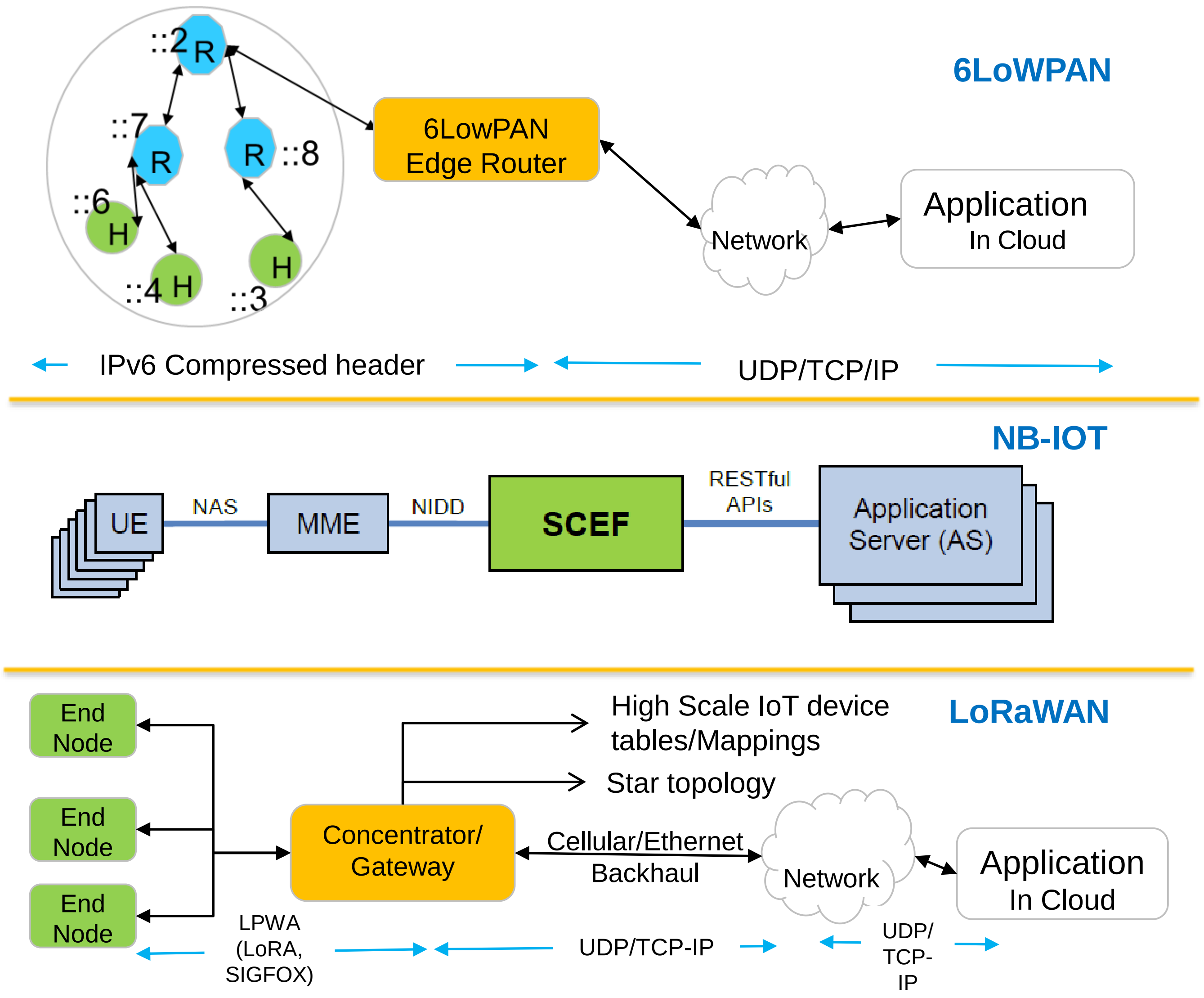
Source eslkidsgames.com


Source redleaders.com

Challenge: **Network Layer Addressing**

- Massive Endpoints
- Application Silos
- Session Continuity

Do we need to Address Every Connected Device by IP?



Many IoT Communication Technologies

Cellular –
- Based on open alliances (SIGFOX, LoRA)
- 3GPP Backed – LTE-M, EC-GSM, NB-IOT

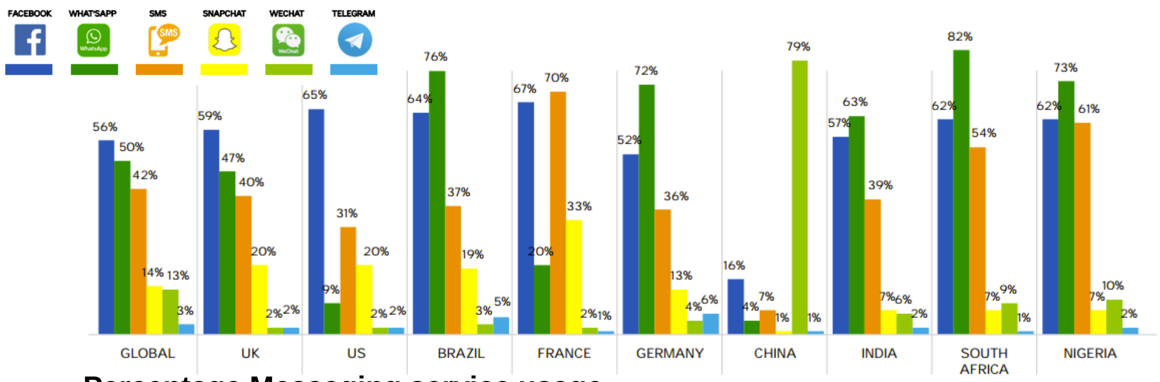
Wireless –
- IEEE 802.15.4: Low Rate WPAN

Protocol	**Addressing Scheme**
6LoWPAN	• Compressed IP
NB-IOT	• Non-IP data support
LoRaWAN	• DevEUI - 64 bit end-device identifier, • DevAddr - 32 bit device address • AppEUI - 64 bit application identifier, • GatewayEUI - 64 bit gateway identifier,

No Clear Single IOT Solution However

✓ Different Requirements and Deployments
✓ Embrace Heterogeneity and Scale
✓ Application or Business logic in Cloud

Network Centric Applications of App-Aware Networks?



Percentage Messaging service usage

Prominent Communications - Chat, Instant messaging Applications

- Multiple User accounts For Multiple Applications
- No Cross-application Communication
- Applications driven communications more complex
  - User Management
  - Active Connection state
  - Application based security (Generally less secure)

A Case for Unified ID Space - <u>What if</u>

- All apps get same unique ID ('who is').
- And talk to each other
- A Network ID recognized uniquely and globally accessible

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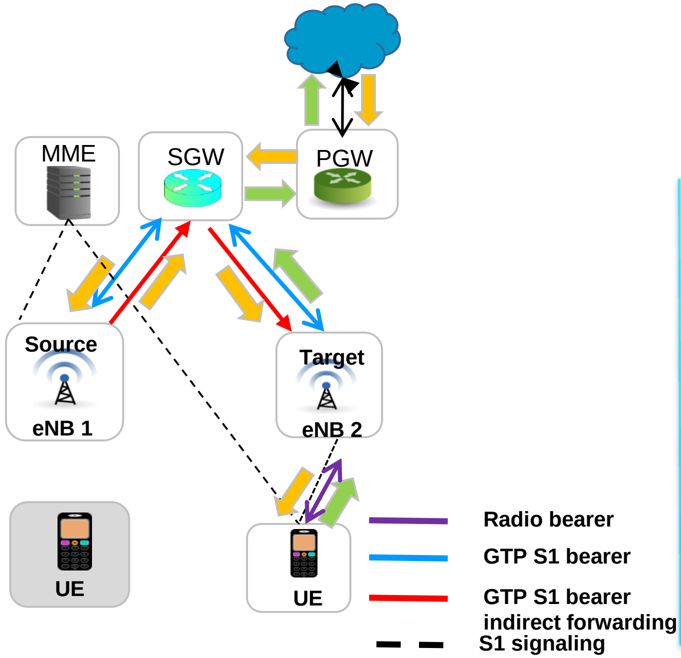
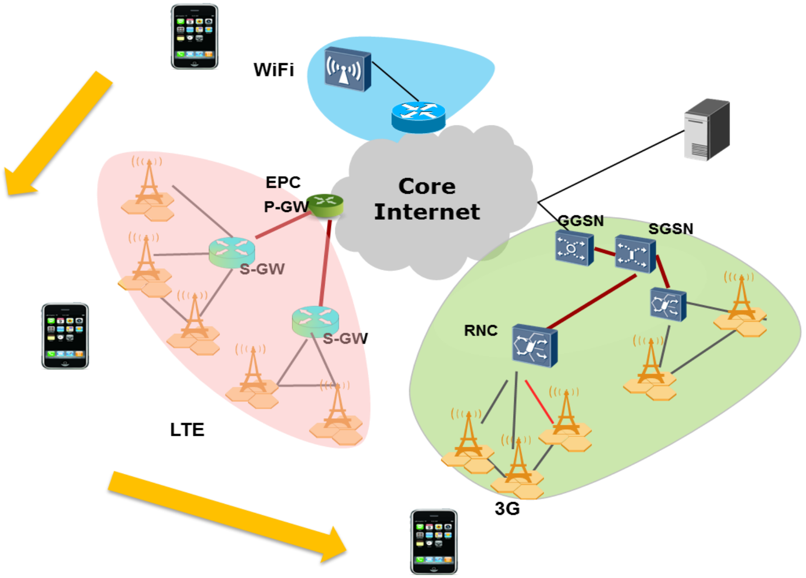
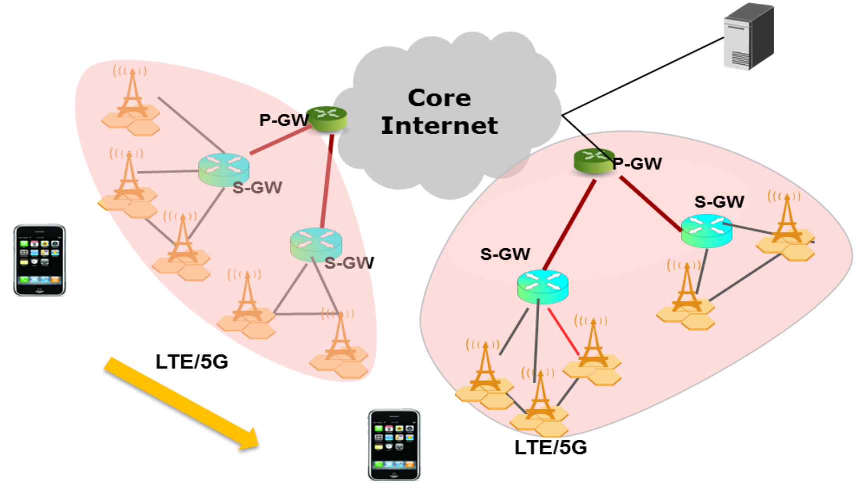
Ubiquitous Connectivity == Session Continuity in Motion







Suboptimal Triangular Routing

- A session is kept <u>live with old location</u>.
- New session is created to re-send data to new location

Move across different Access

- <u>IP Address changes</u> when access changes causing service disruption

Lack Of Session Continuity

- Even in same access, for example LTE, PGW to PGW, GTP <u>Tunnel is re-established</u>
- Session is not preserved.

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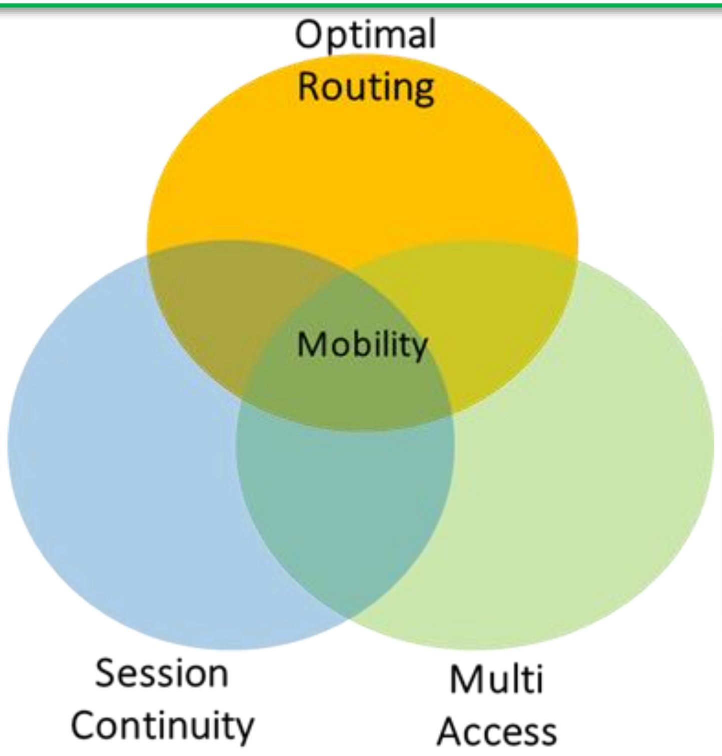
State Of the Art - Standardized solutions

SDO	Solution	Methodology	Advantages	Limitations	Market Proven
IETF	Mobile IPv4	Home Agents, Home Address, Care-of addresses	Use of IPv4, retain same ip address	Handover latency, signaling overheads in transition, suboptimal triangular routing, Limited QOS	
IETF	MIP V6	Address Autoconfig, autodiscovery of neighbors, Care-of-Addresses use of ipv6 hdr options for destination options	Always On Use of IPv6 Session persistence	Handoff latency, Limited awareness of heterogeneity, requires kernel changes, Security issues	
3GPP	3G/GTP	Tunnels through eNB, S-GW and P-GW	Fast handoff	Tunnel re-creation on move, no session continuity.	Yes
3GPP	4G/LTE/GTP	Tunnels through eNB, S-GW and P-GW	Fast handoff	Tunnel re-creation on move. Service continuity is limited within a P-GW	Yes
IETF	Proxy Mobile IPv6 (PMIPv6)	Mobile Access Gateway (MAG) and Location Mobility Anchor (LMA)	Fast handoff retain same ip address	Session continuity limited to local administrative domain, centralized LMA may not scale well.	Yes
IETF	Distributed Mobility Management (DMM)	Mobility anchors, partial session distribution	Fast handoff	Triangular routing only for on-going sessions same as Mobile IP. Optimized for new sessions only. No RFC yet	
IETF	LISP	ID separation from location. Both ID and locator are IP address based	Use of ID over IP	Under Research	waiting for multi-vendor adoption.

Achieving Ideal Mobility Solution

Support Optimal Routing

- Any indirect session path adds to latency as well as resource inefficiency in the Network



Session Continuity

- Mobility means location changes, leading to IP address changes and thus a session change.
- To Preserve session even with IP address changes

Same Session across multi-access

- Uniformly and uniquely identify a session independent of any Access (IP/non-IP)

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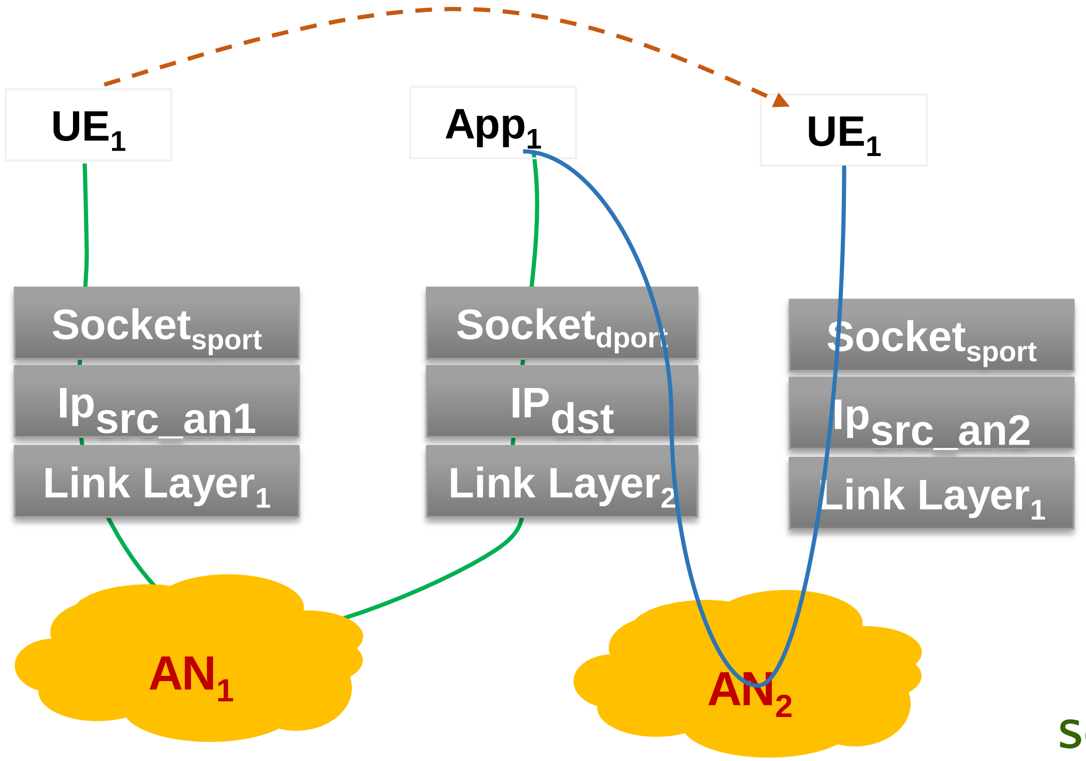
Review Of IP Network Layer Problems



Review of Scenarios

1. Massive Endpoints and every thing is connection worthy
2. Session Continuity and mobility support
3. Cross-Siloed App communication

$Session_{old} = \{Ip_{src\_an1}, IP_{dst}, Socket_{dport}, Socket_{dport}\}$

$Session_{new} = \{Ip_{src\_an2}, IP_{dst}, Socket_{dport}, Socket_{dport}\}$

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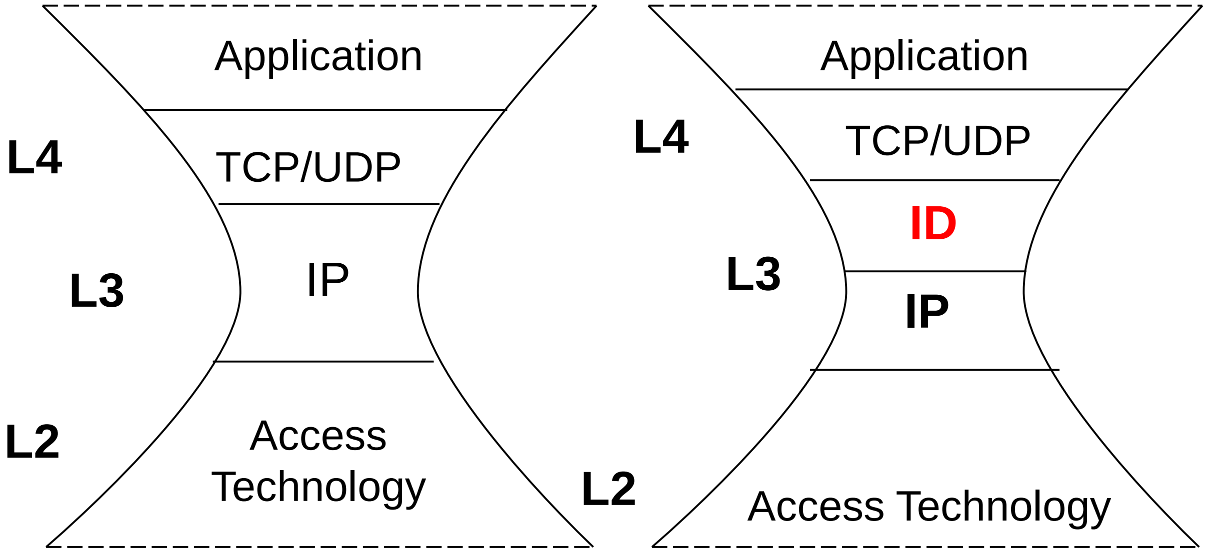
ID Oriented Networking - ION

Splitting Network Layer

Dissociate Location (Point of Attachment) from the Object/Entity itself



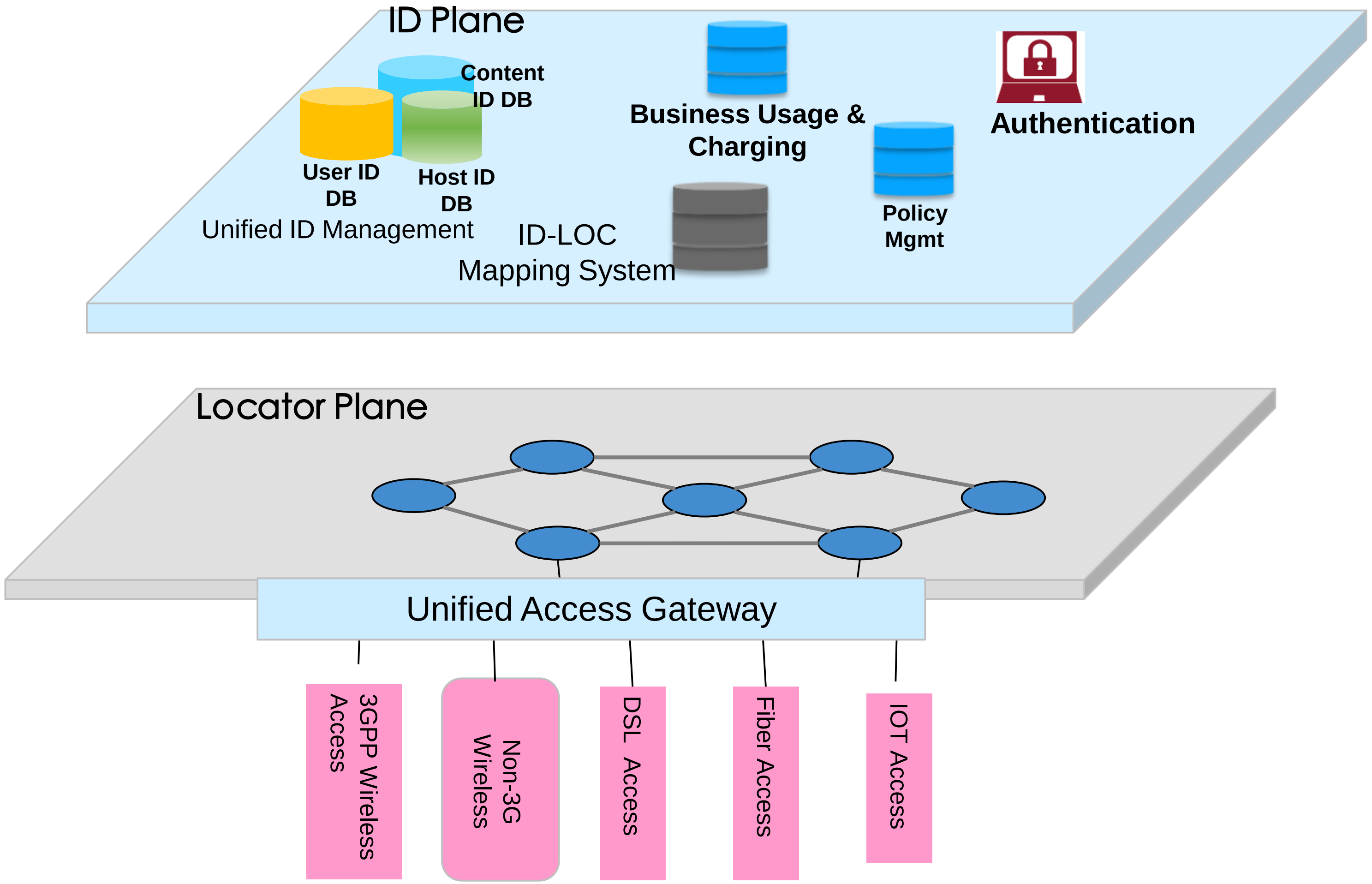
ID Sublayer

- Universal mobility and global reachability
- A user, host, content, and virtual network
- Remains unchanged

Locator for routing:

- Address aggregation and
- Longest prefix matching
- Locator varies from place to place

ID Oriented Networking (ION)
A Viable Approach



ID Sublayer

- Caters to management and mapping of Identities for various purposes.
- Eliminates tunnels such as GTP

Locator Sublayer

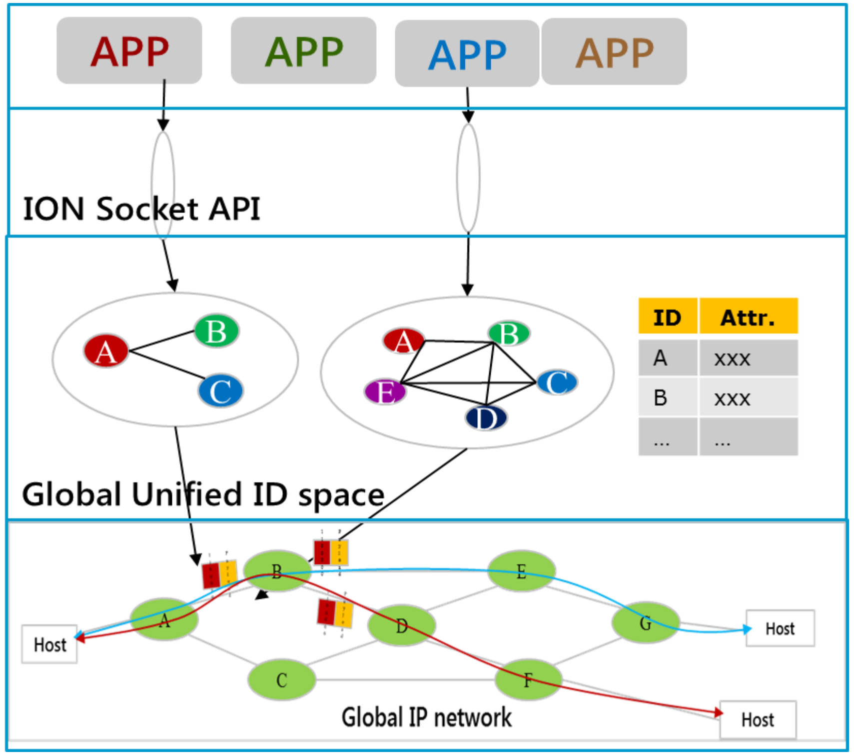
- Same as Infrastructure routing/switching
- An Endpoint may have an address

ION Makes Networks App-Friendly

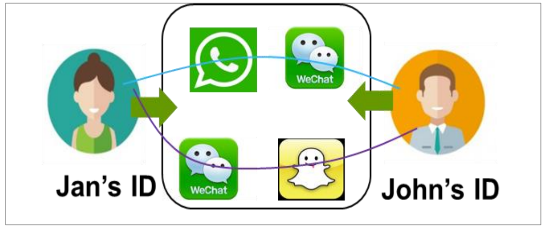
No Application Isolation

ION Sockets

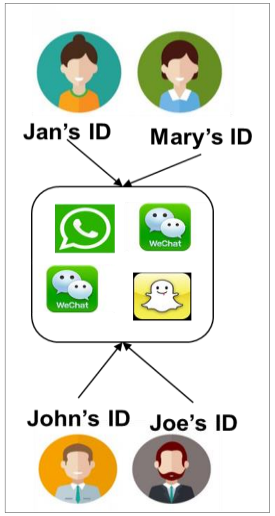
- Connect with ID based sockets
- IP layer locates source and destination ID and sets up path



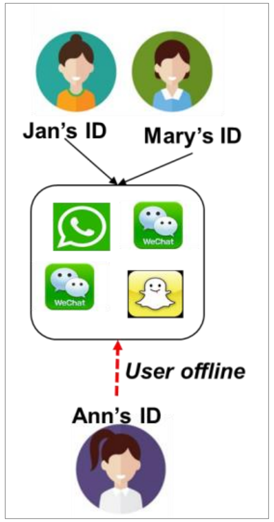
ID	Attr.
A	xxx
B	xxx
...	...



1. Point to Point



2. P2MP & MP2MP



3. Asynchronous

Unified ID Space

- All apps get same unique ID ('who is').
- Mapping system guarantees ID is unique and globally accessible

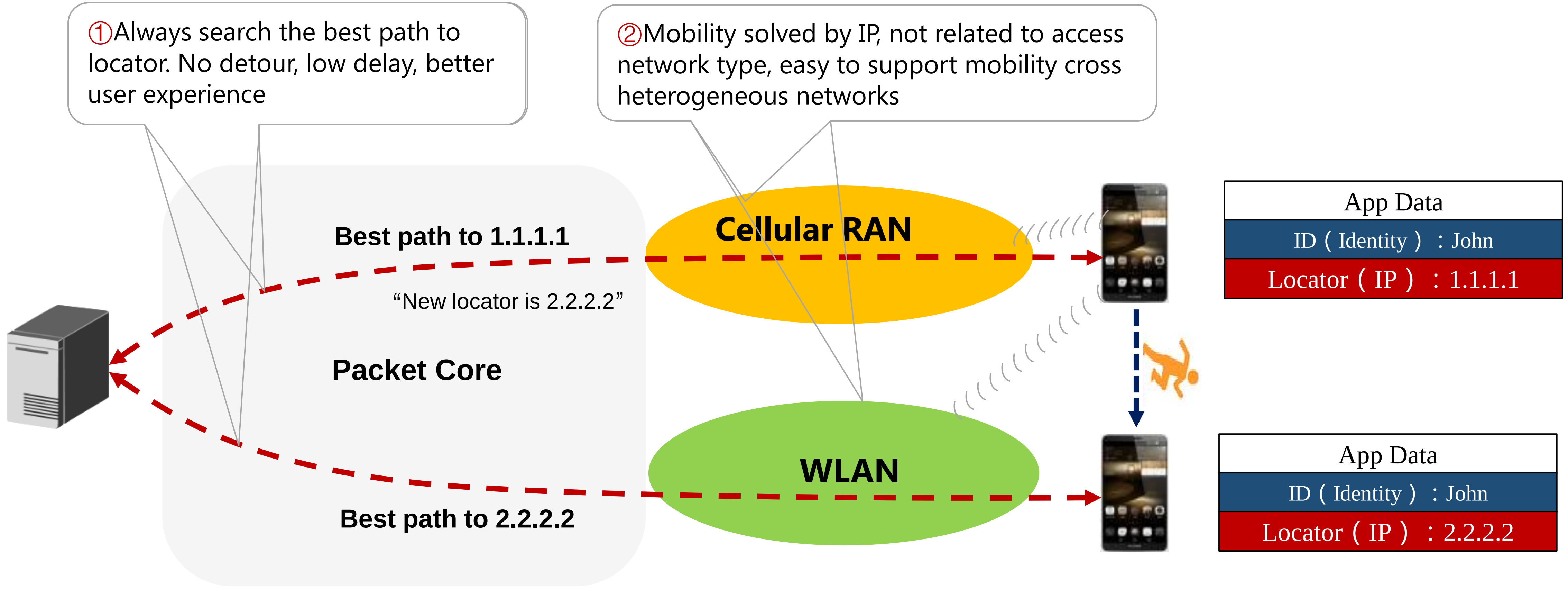
Sessions based on ID

1. Point to Point
2. Group Communication with ID
3. Support Active/Passive Comm.

One Place to Manage

- Unified ID Plane

ID Plays a Central Role in Mobility



1. No Detour to EPC Anchor
   - End-to-End latency is minimized and the user will have a better experience.
2. Access network type independent mobility
   - No mobility gateways or agents

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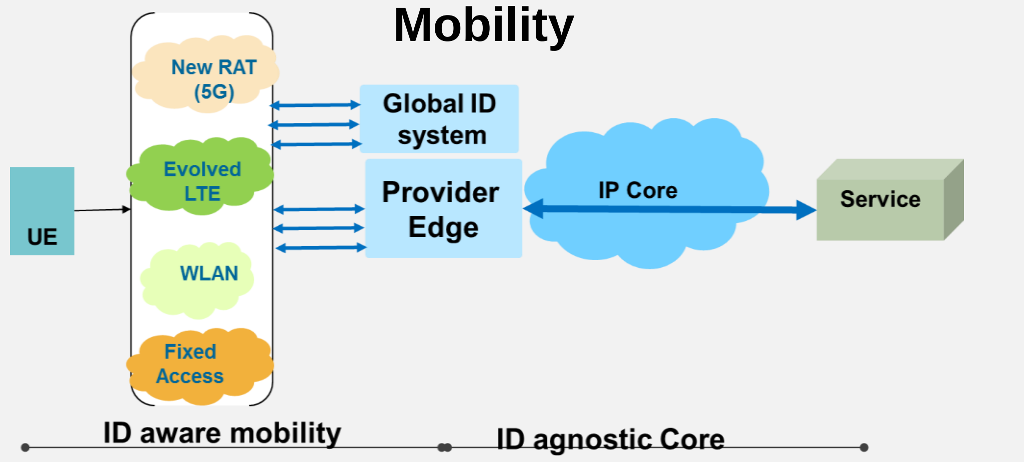
ION Unlocks New Opportunities Beyond Mobility



Benefits and Opportunities

- Delivers Better Service Experience
  - Optimal traffic path selection
  - No detours to mobility anchor point
- Simplified Network Operations
  - Unified ID plane for any fixed and mobile access
- ID Agnostic Stable Core
  - FIB remains locator based
  - As user moves, no route change triggers

- Communication
  - P2P Communications without servers
  - Cross-silo communication possible
  - ID based Group-communication (PIM free)
- Accelerated applications deployment
  - Network/Topology change agnostic
  - Focus on business logic not network
- Refined Edges
  - Fine grained ID aware TE, Policy, LBs
  - ID based End to End Security

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ION Protocols: Examples

- **LISP**

  Location Identifier Separation Protocol

- **HIP**

  Host Identity Protocol

- **HIMALIS**

  Heterogeneity Inclusion and Mobility Adaptation through Locator ID Separation

- **LINA**

  Location Independent Network Architecture

- **GSE**

  Global, Site, End system

1977

2015

Challenge: **Transport Layer Throughput**

- Ultra High Definition Media
- RTT
- Packet loss

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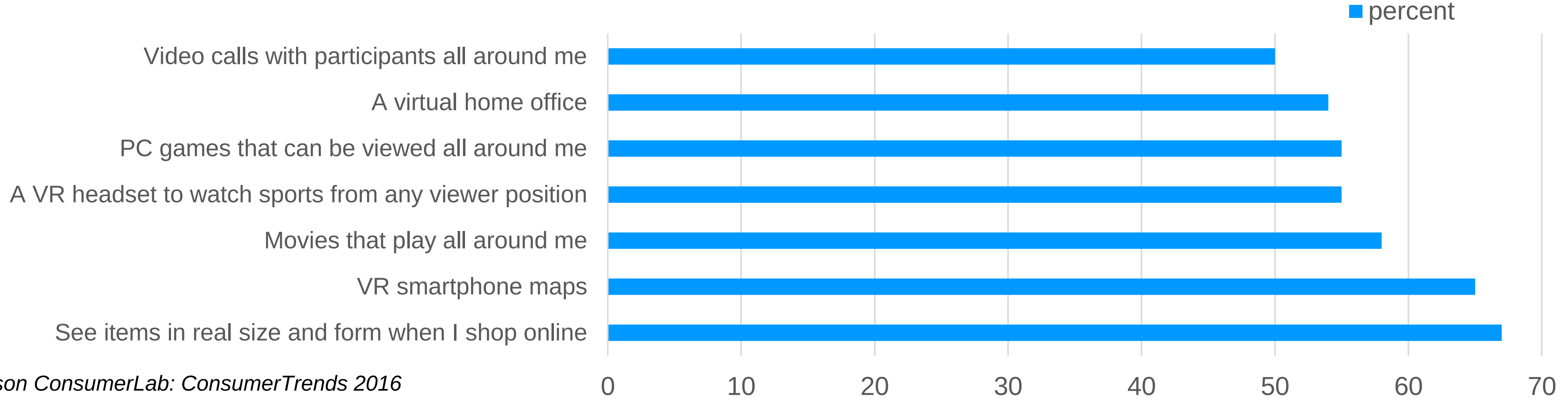
Recent Transport Trends – Immersive Experience

Consumer survey on VR services

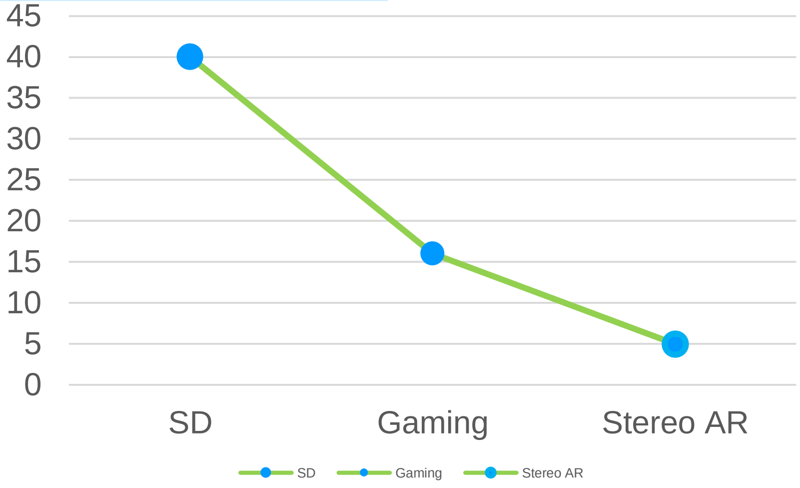


Source: Ericsson ConsumerLab: ConsumerTrends 2016

VR User Experience Challenges

- Frame Latency – Decouples from virtual world
- Causes disorientation

Max Frame Latency (ms)



Source: http://blogs.valvesoftware.com/abrash/latency-the-sine-qua-non-of-ar-and-vr/

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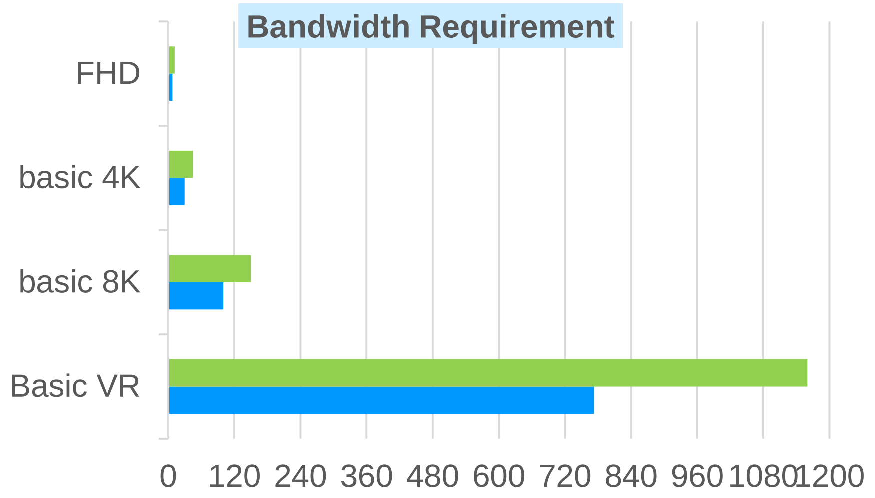
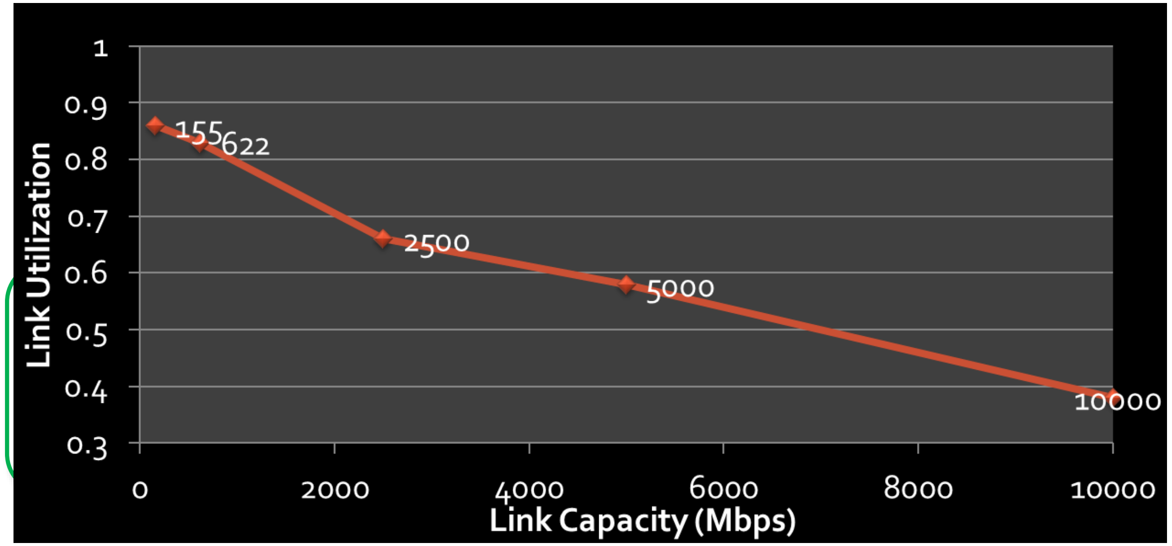
Available bandwidth is not used well





Bitrate for a video format

bits per pixel X resolution X frame rate

Conventional TCP Throughput

$$Throughput \leq \min\left(BW, \frac{WindowSize}{RTT}, \frac{MSS}{RTT} * \frac{1}{\sqrt{p}} \right)$$

Example - Packet Loss Consequences

Bandwidth = 100 Mbps; *Delay* = 60 ms, *packet loss rate* 1/10000,

Actual throughput: 23 Mbps

NS-2 Simulation (100 sec)

- Link Capacity = 155Mbps, 622Mbps, 2.5Gbps, 5Gbps, 10Gbps,

Drop-Tail Routers, 0.1BDP Buffer

- 5 TCP Connections, 100ms RTT, 1000-Byte Packet Size

Source: Presentation: "Congestion Control on High-Speed Networks", Injong Rhee, Lisong Xu, Slide 6

Why Application Throughput Matters?

Bandwidth requirement	SD	HD	FHD	Quasi 4K	Basic 4K	Ultra 4K	Quasi-8K	Basic 8K	Ultra 8K	Quasi VR	Basic VR	Ultra VR
Resolution	640*480	960*720	1920*1080	3840*2160			7680*4320			4K*3 (2K*2K*2)	10K*3 (5K*5K*2)	32K*3 (16K*16K*2)
Frame rate	25/30	25/30	25/30	25/30			25/30	50/60	100/120	50/60	100/120	100/120
Color depth	8	8	8	8			10	12	14	10	14	14
Sampling/ Compression	YUV 4:2:0 & H.264			YUV 4:2:0 & H.265/HEVC								
Minimum bit rate (M bit/s)	2	4	8	15			50	100	220	68	773	7920
Minimum bandwidth (*1.5, M Bits/S)	3	6	12	23	45	75	75	150	330	101	1160	11880
Delay(ms)	100	100	100	50	50	40	40	25	25	20	15	15
Packet loss ratio	1.0E-03	1.0E-04	1.0E-04	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-05	1.0E-06	1.0E-05	1.0E-06	1.0E-08

Transport Optimizations and Improvements Solution Space

End node improvements

Using Packet Loss and/or RTT to improve or multipath

Example: Reno, CUBIC, Fast TCP, Vegas, MPTCP

Network Assisted

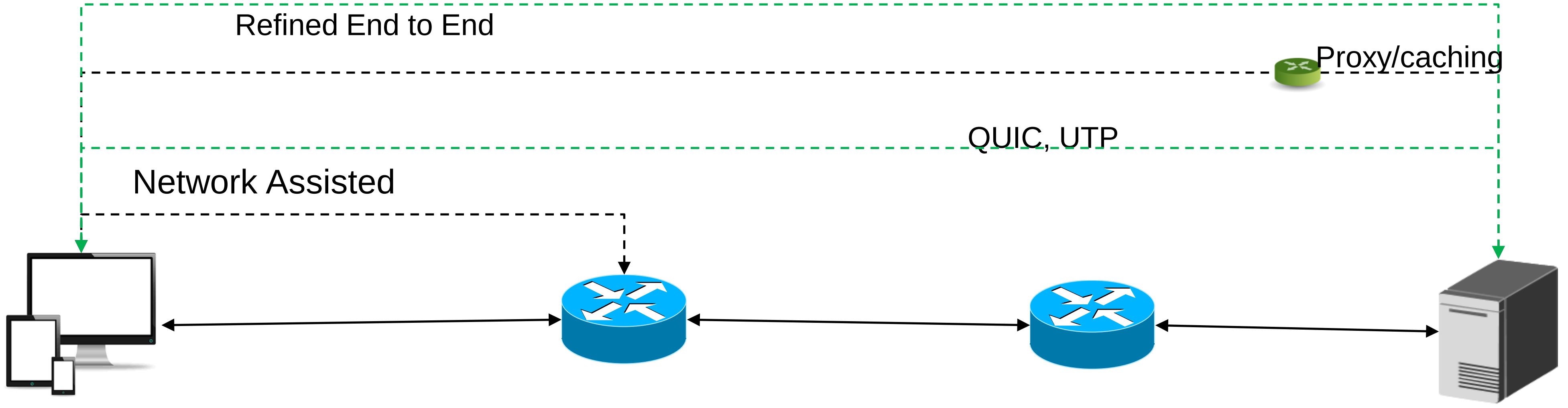
Explicit congestion notification or content caching

Example: XCP, VCP, RACE (vendor's)

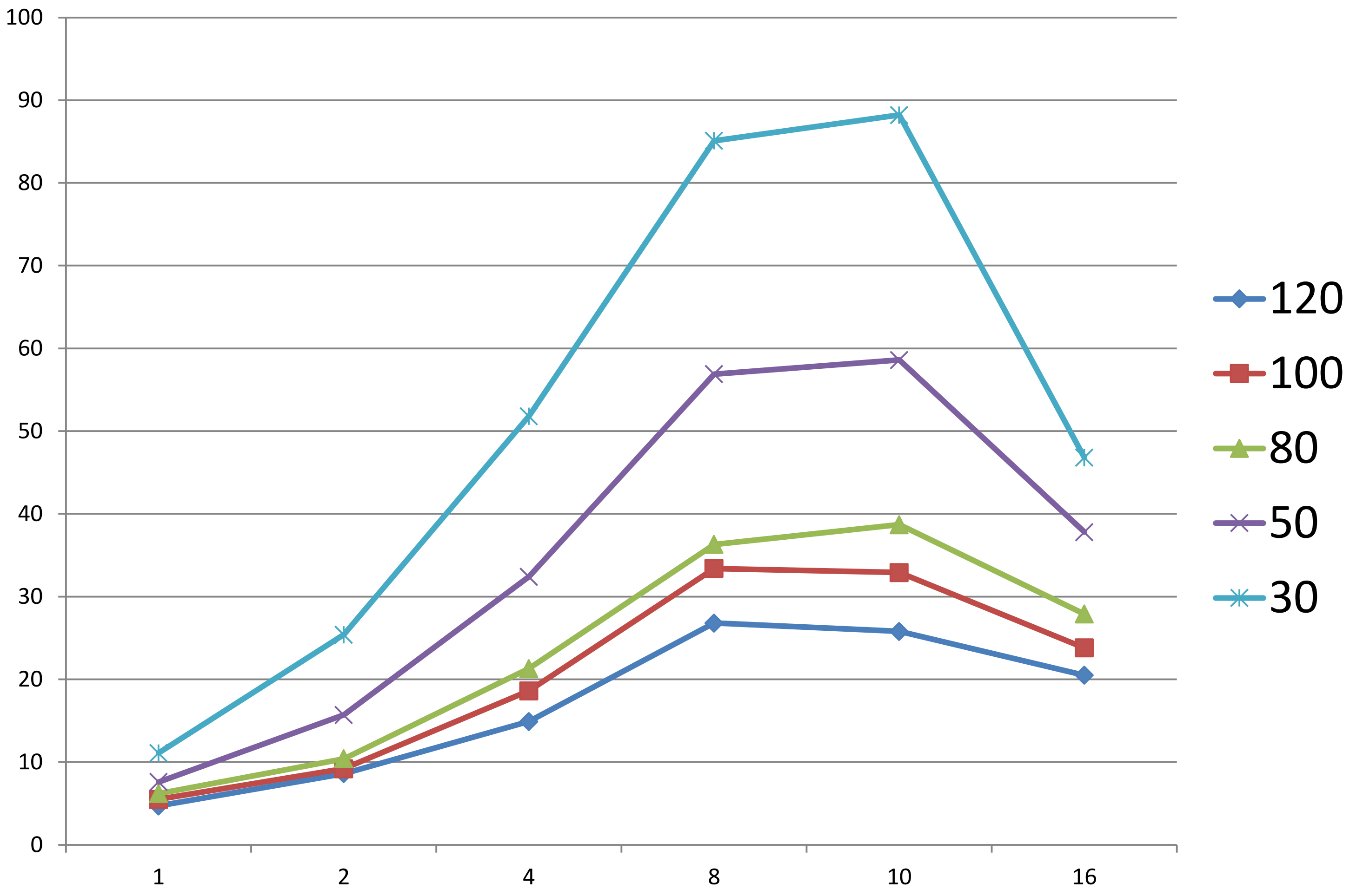
Other Transport

Considering Non-TCP options

Example: UTP, QUIC



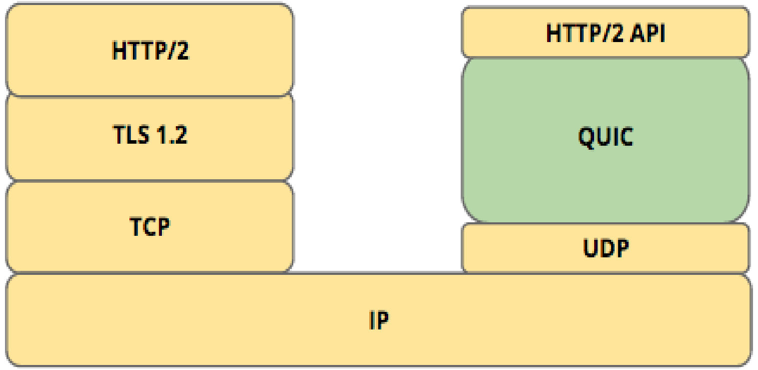
Multiple paths - Improving Throughput using MPTCP

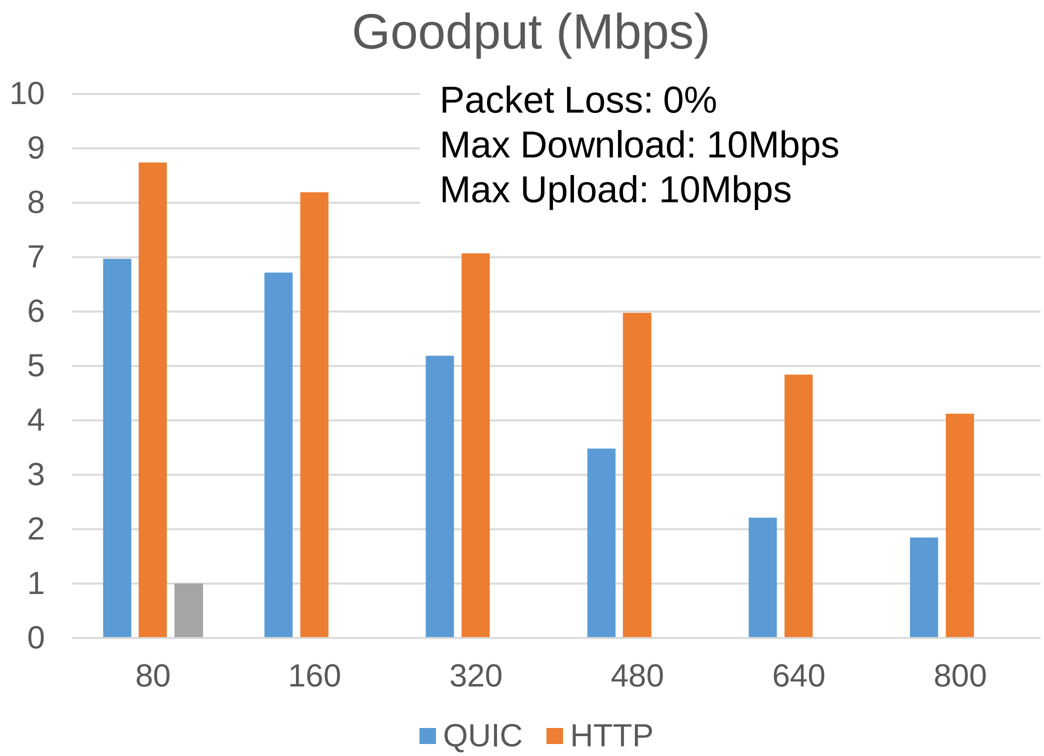


Increases the number of parallel flows

As the number exceed 10, flows start to compete for resource

QUIC – A new Transport Protocol





- Replace TCP + TLS with UDP based solution
- Fast than TLS in secure connection setup
- Solve TCP line blocking for HTTP

http://www.connectify.me/blog/taking-google-quic-for-a-test-drive/

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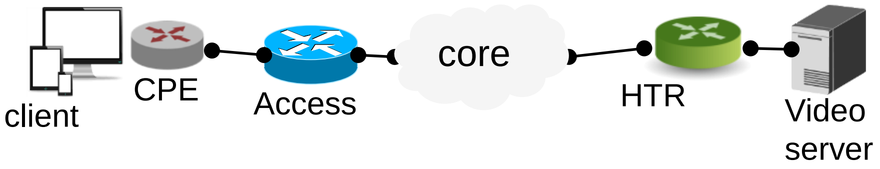
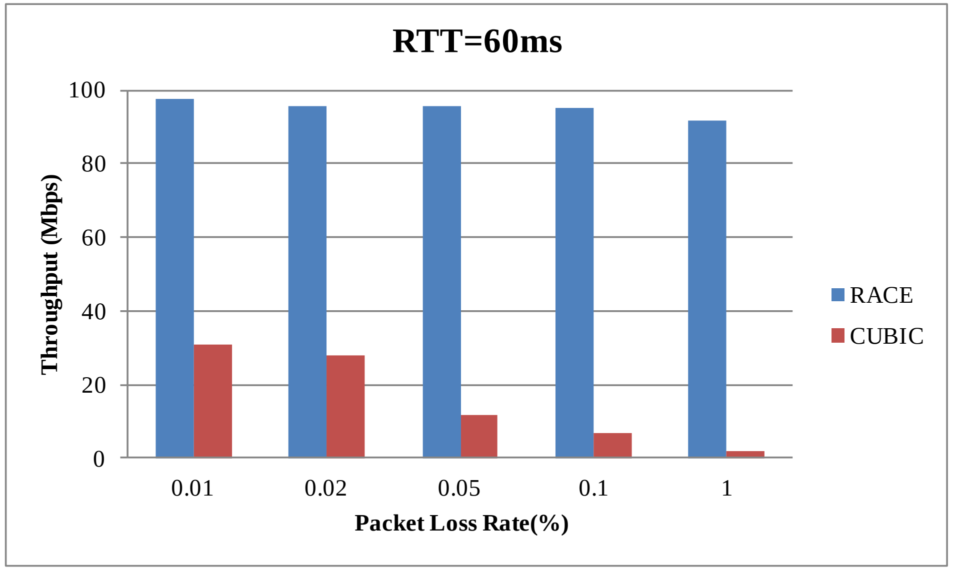
Network based - RACE and HTR (High Throughput Router)





Source: EANTC

RACE - Rapid CWND size increase

- Adjustable target rate,
- Distinguishes congestion from random packet losses
- Efficient adjustment of the CWND size to achieve high throughput.

Intelligent Data Analysis

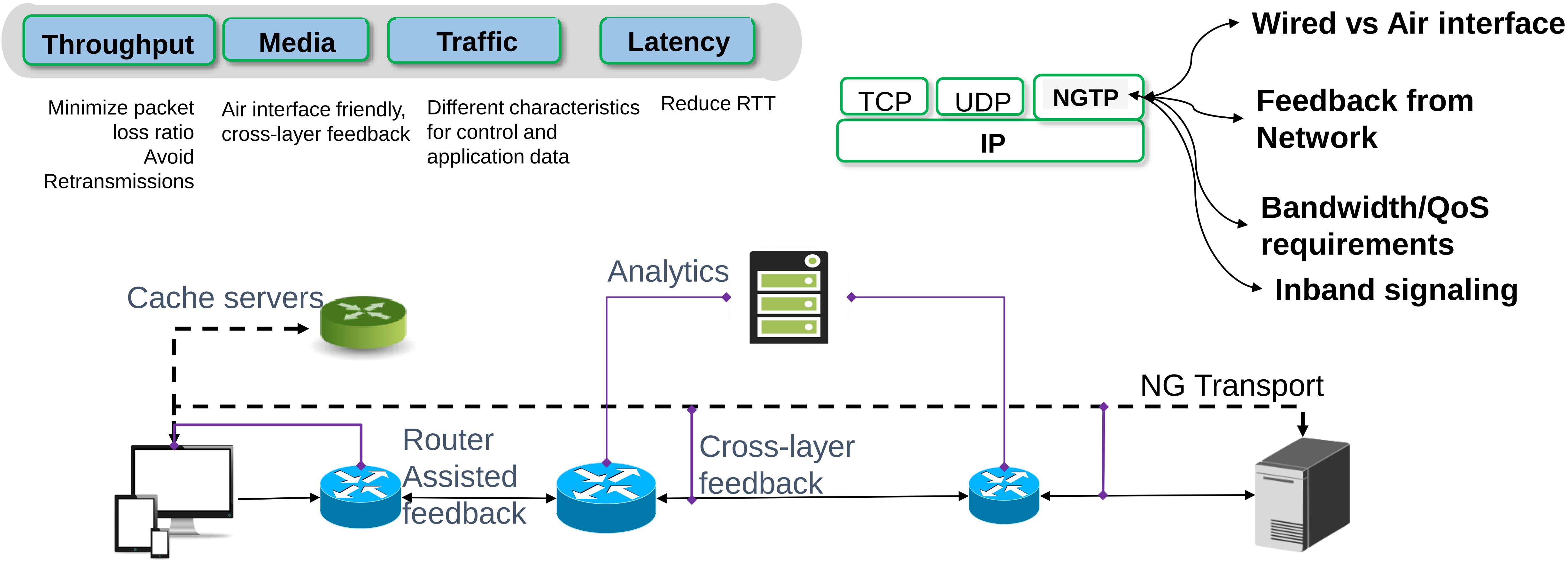
- Collects multi-dimensional application and network information of each TCP flow
- Engine to process the application-layer requirement and network-layer status to obtain information for intelligent congestion control identification

State Of the Art - Standardized solutions

Solution	Methodology	Advantages	Limitations	Market
TCP	End to end byte-based transport, Congestion window control 3-step connection setup	• Reliable, in-order delivery	• Line header block • Poor real-time ability • Difficult multi-homing implementation • Vulnerable to denial of service (DOS) attacks (SYN flood)	All over
SCTP	Stream-based Reliability Supports ordered un-ordered	• Selective acknowledgement • Eliminates head of line blocking • Reduces DOS due to 4-way connection (cookie) • Congestion avoidance via fast retransmission. • Multihoming thru heartbeat	• Requires App changes • No load sharing	SS7, NAS signaling on LTE
MPTCP	Multiple path using TCP options	• No app changes • Resilience through • usage of alternative path • Can do load sharing	Scale issues for high number of multiple connections	Mobile devices
QUIC	Session Establishment, Flow Control Error Correction, Congestion Control	• Fast connection setup	Is mainly used in single browser environment.	Yes

Transmission Media Aware Transport Efficiency

A Comprehensive Approach



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Potential Research ideas of new transport

Transport layer based on measurement

(RTT, loss) ≠ congestion
Classic CC only measures RTT and loss rate, can not measure the congestion.

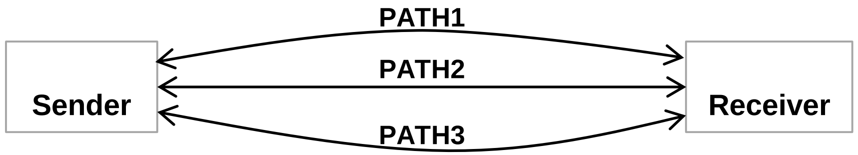
The real congestion is determined by the available BW of the bottleneck. How to get that info?

Key idea: Introduce accurate measurement into new CC to measure available BW and network delay to meet the high throughput and low delay requirements of VR/AR.

Multi-stream transport

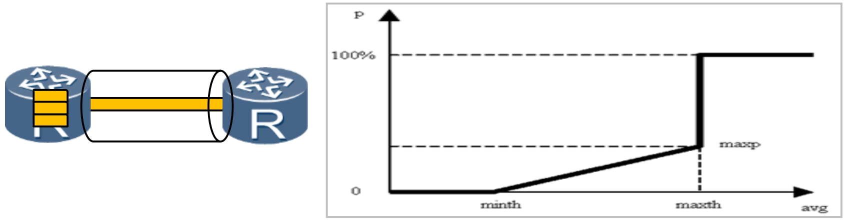
The problem of current mutli-stream transport: MPTCP, which is mainly focused on reliability and improving throughput moderately, lack efficient algorithms in high throughput .

Key Point: Researching on a new parallel CC algorithm for the high throughput & low latency requirements of VR/AR.



NGAQM

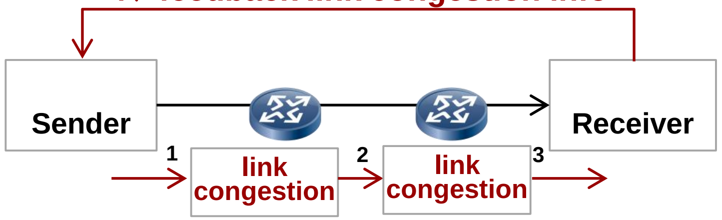
Key point: 1) VR needs low latency & high throughput. So we are researching on a new AQM Algorithm with small buffer instead of large buffer. 2) Part of port utilization is converted to queue, instead of physical buffer.



NGAQM---virtual port queue

ECN+

Key point: network layer and transport layer interact with each other. The network devices feedback the link idle rate and congestion info, and then transport layer increase cwnd in one step based on the link idle rate, which can improve the throughput and meet the low delay requirement.

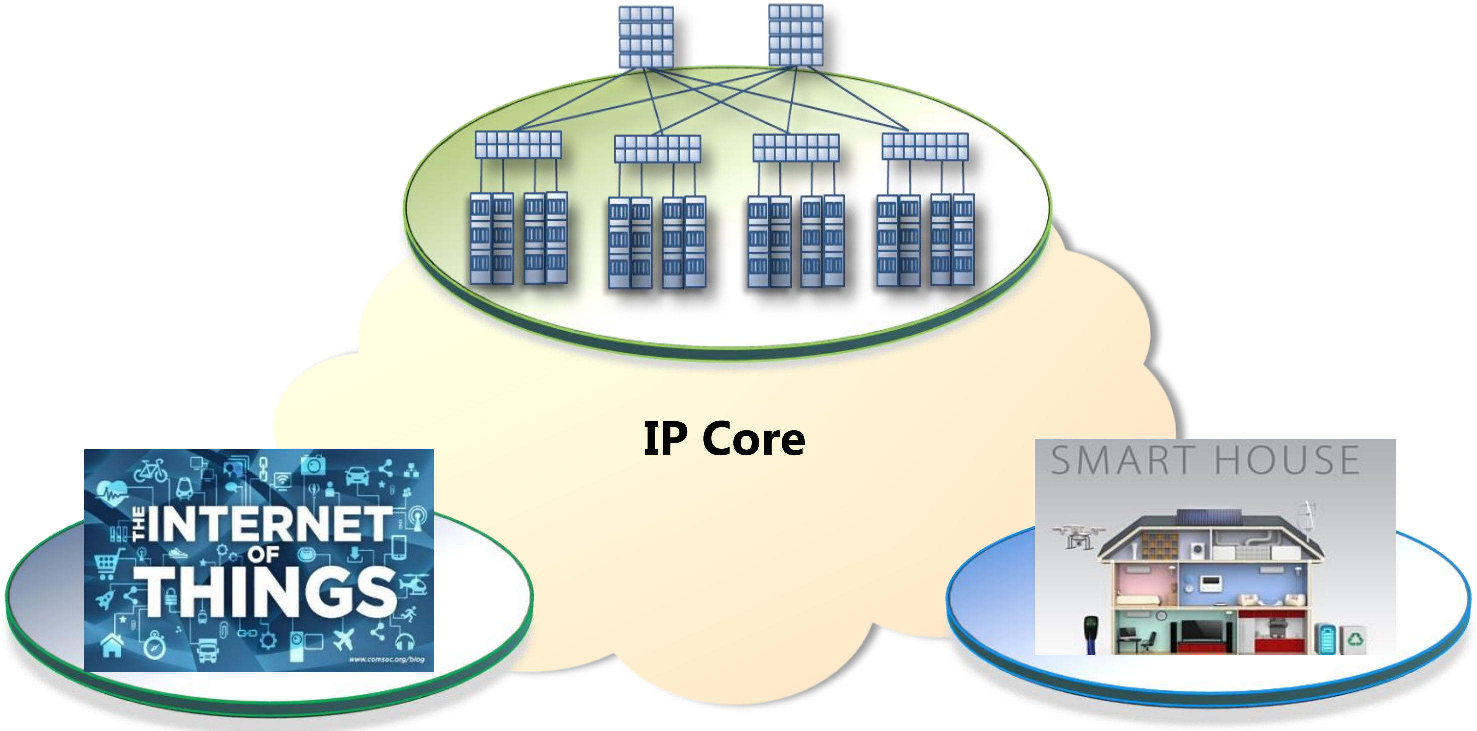


Autonomic Networking

Intelligence and Security DNA

Why Intelligent Networking?

Enterprise Networks | **Home Networks** | **IoT Networks**



Complex Enterprise Networks

- Bulky configurations
- Destabilizing network & service coupling
- Intricate application policies

Smart Home Networks

- Owners lack expertise to operate networks
- Low maintenance, non-disruptive networks

Scale of IoT Networks

- Trillions of Things are connected to the Internet
- Can not scale through IP based schemes

Conventional routing protocols were not designed for such diverse eco-systems

Organizing Next generation of Networks

Enterprises

Tedious Manual Planning (Error prone)

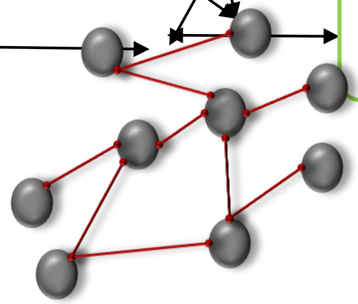
- Bandwidth planning & Resource Allocation — ~ 80K ACLs in DC
- Maintenance Schedules — ~3 days to isolate faulty port
- DDoS Attack Prevention
- Fault Isolations
- Routing Configurations — ~100,000 config-lines

Minimize Human Intervention in Network Design & Operations

IoT Networks

Can Not Operate With Conventional Techniques

- Resource Adaptiveness — Properties differ w/ RATs
- Various Sensor types — Sporadic traffic bursts
- Energy Sensitive — Light weight routing
- Environmental Changes — Multiple sensors deliver services together
- Volatile Topology — Static configurations cannot scale



Address Massive Scale And Variations, Environmental Constraints

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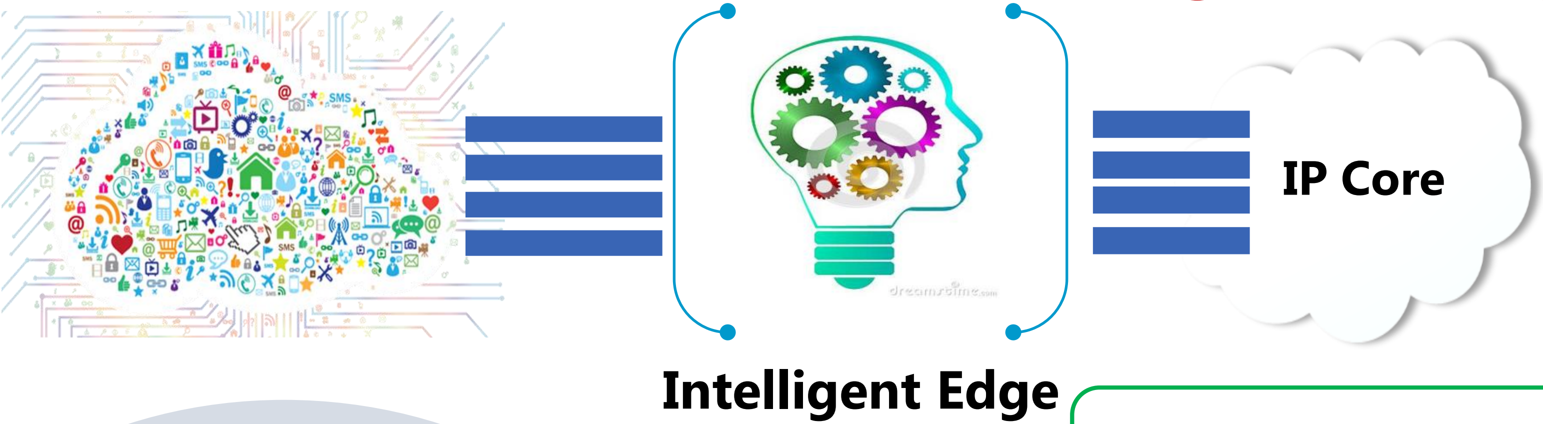
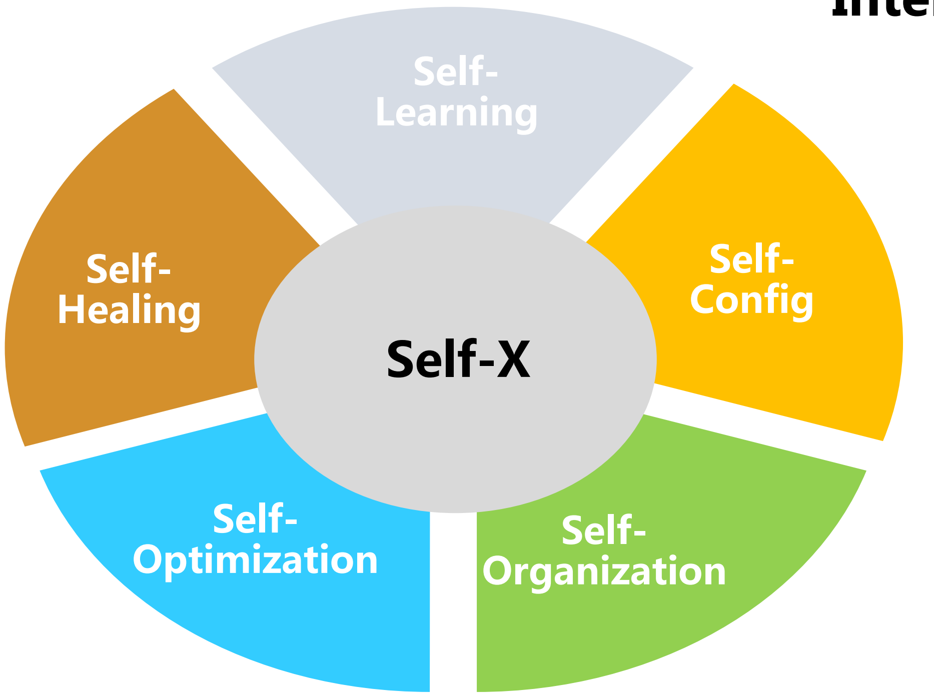
Self-X Network for Intelligent Edge





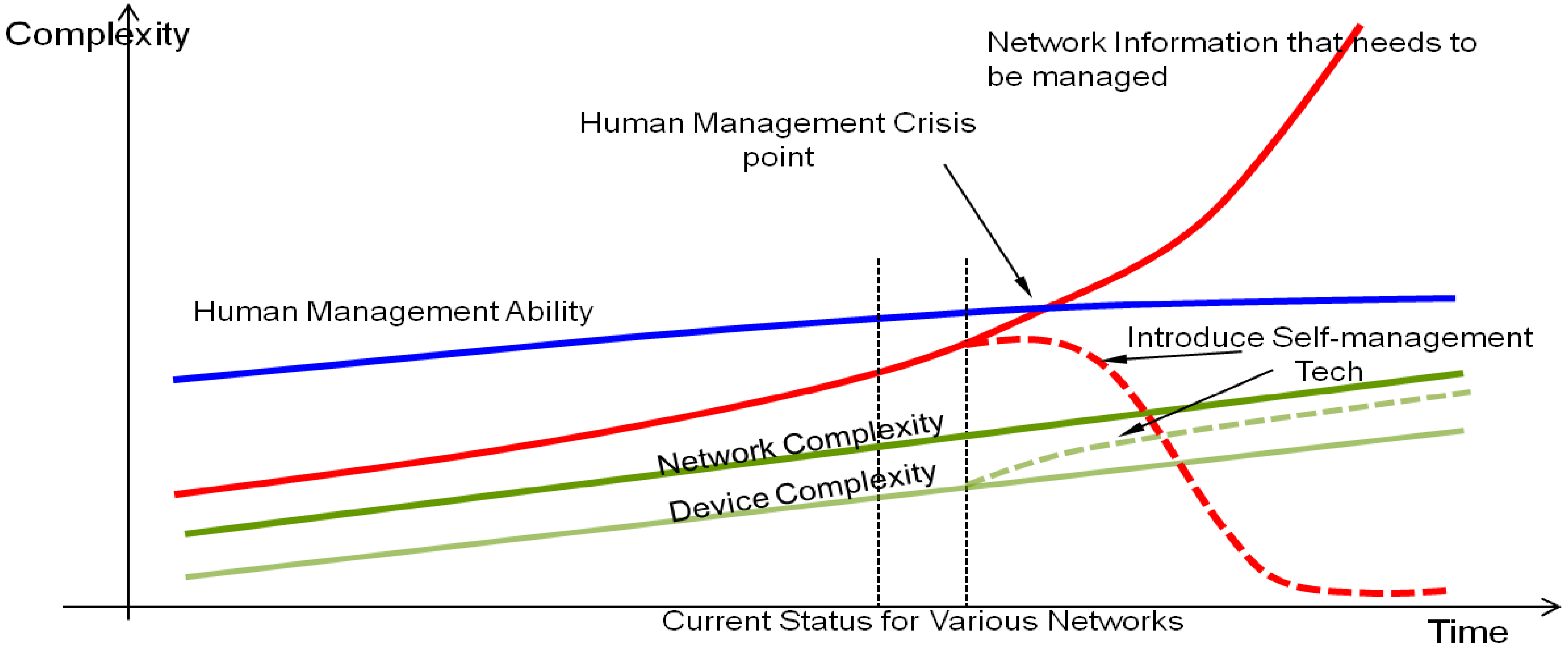
Network modeling based IT service and network node auto-connect

Protocol and algorithm for self-organization network

Auto detect, self protect for network attacking

Auto monitoring, self-repair for network defects

Self-Organizing
Reduce management complexity



A more flexible, extensible and self-management system is urgently needed

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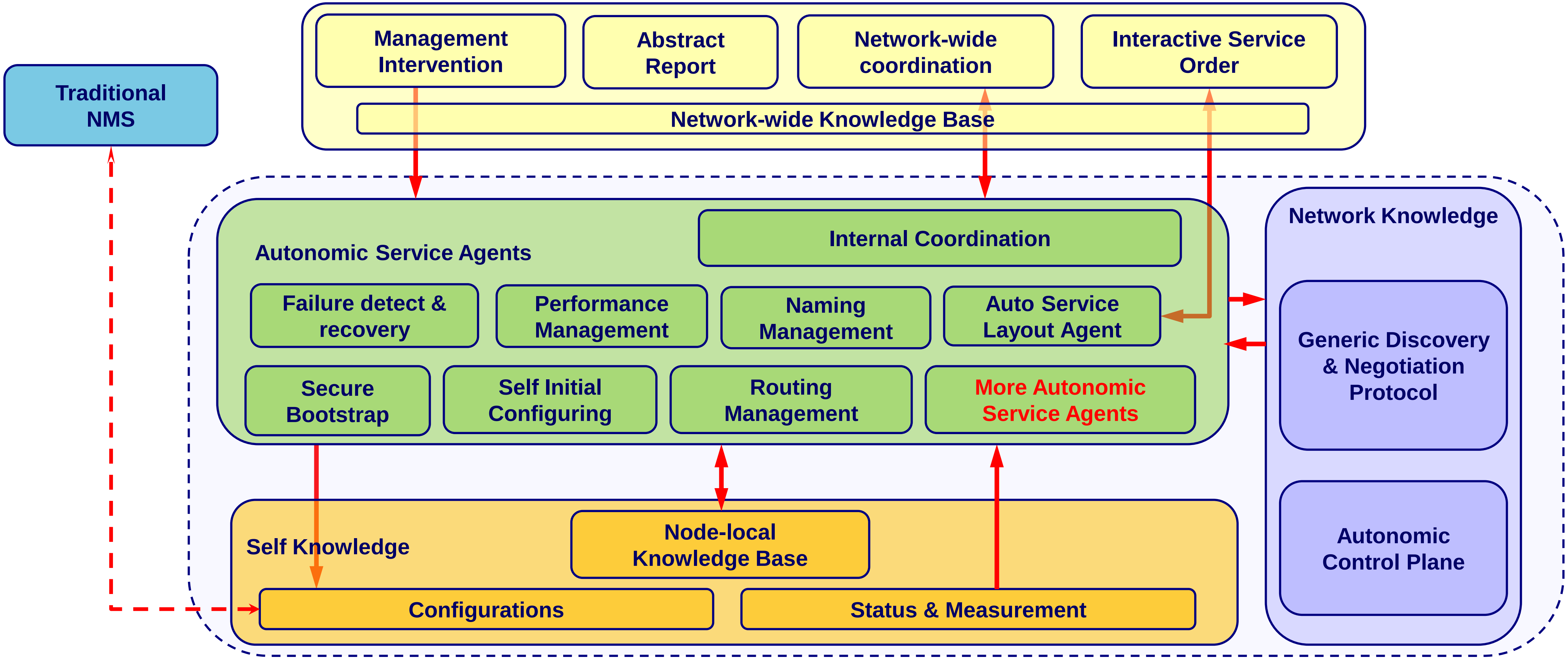
Architecture of Protocol-oriented Autonomic Network



- Universal autonomic-oriented signaling protocol platform, which supports generic discovery & negotiation & synchronization functionalities, independently from any specific objectives
- The intelligent devices would be able to decide the best behaviors by themselves with the knowledge supplying from other node and network-wide knowledge base

Machine Learning - Mechanism for Self decision

Machine Learning can be used to extract rules used in network management and classify the various statuses inside and outside the system (obtained from measuring and monitoring)

- Traditional system design – Handling a known scenario explored during design time
- If not, the case is classified as “uncertainty”. Artificial intelligence is needed for this case

Artificial intelligence in Network systems can take decisions and makes the system capable of solving problem

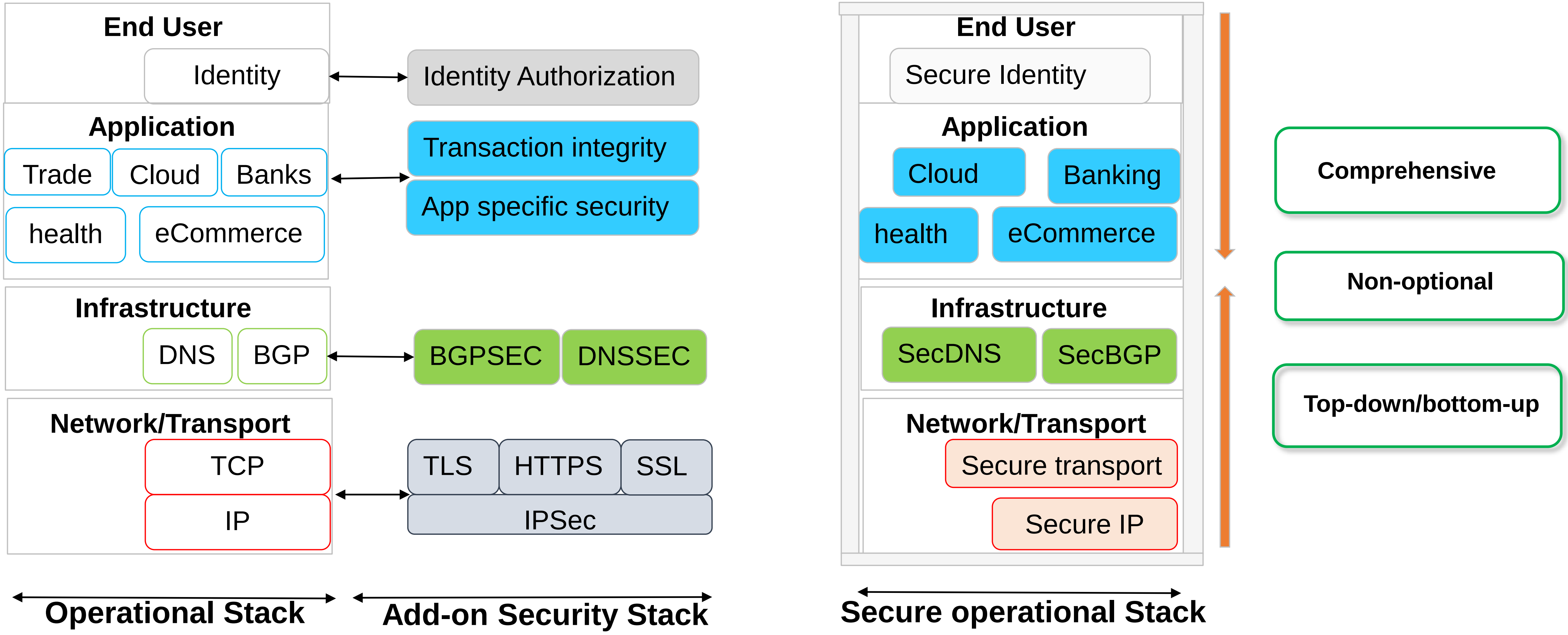
Algorithms with generic characteristics can be used. No need for a specific logic for every new situation

- Using artificial intelligence for data analysis; complementing with use of traditional data analysis in artificial intelligence

Machine learning is the only way to percept unknown without human intervention.

- Real-time decision needs processed rules and real-time small data

Security Is Fragmented



Protocols for IP 2020: A Summary

5G | IoT | AR/VR

Self-X Networking
Autonomic Networking

Transport Layer — New Transport (Maximize Throughput, Minimize Congestion)

ID Layer — ID for "Globally" Unique Identity (Mobility-Embedded)

Network Layer — IP Address as Genuine Locator (Connectivity-Centric, Longest-Prefix Match)

Security DNA

Thank you

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