# IP 2020

## Towards Next Generation Internet for 5G, IoT, and Immersive Experience

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# Agenda

- Introduction (Trends for IP2020)
- Ubiquitous Mobility
- ID-Oriented Networking
- New Transport
- Self-X Networking
- Security and Trustworthy Network
- Concluding Remarks

# Predicting Future

- Lot of vision and imagination
- Jules Verne, 1863, applied observation and science to predicting the next century in his article “Paris in the Twentieth Century”.
- His prediction for Paris in 1960 for gasoline powered cars, TV, elevators, air conditioning, fax machines, high speed trains …
- In 1865, he detailed a mission to moon in an article “From Earth to Moon”. This resembled the eventual mission in 1969.
- He was not a scientist, but interviewed scientist about their thinking and research extensively.

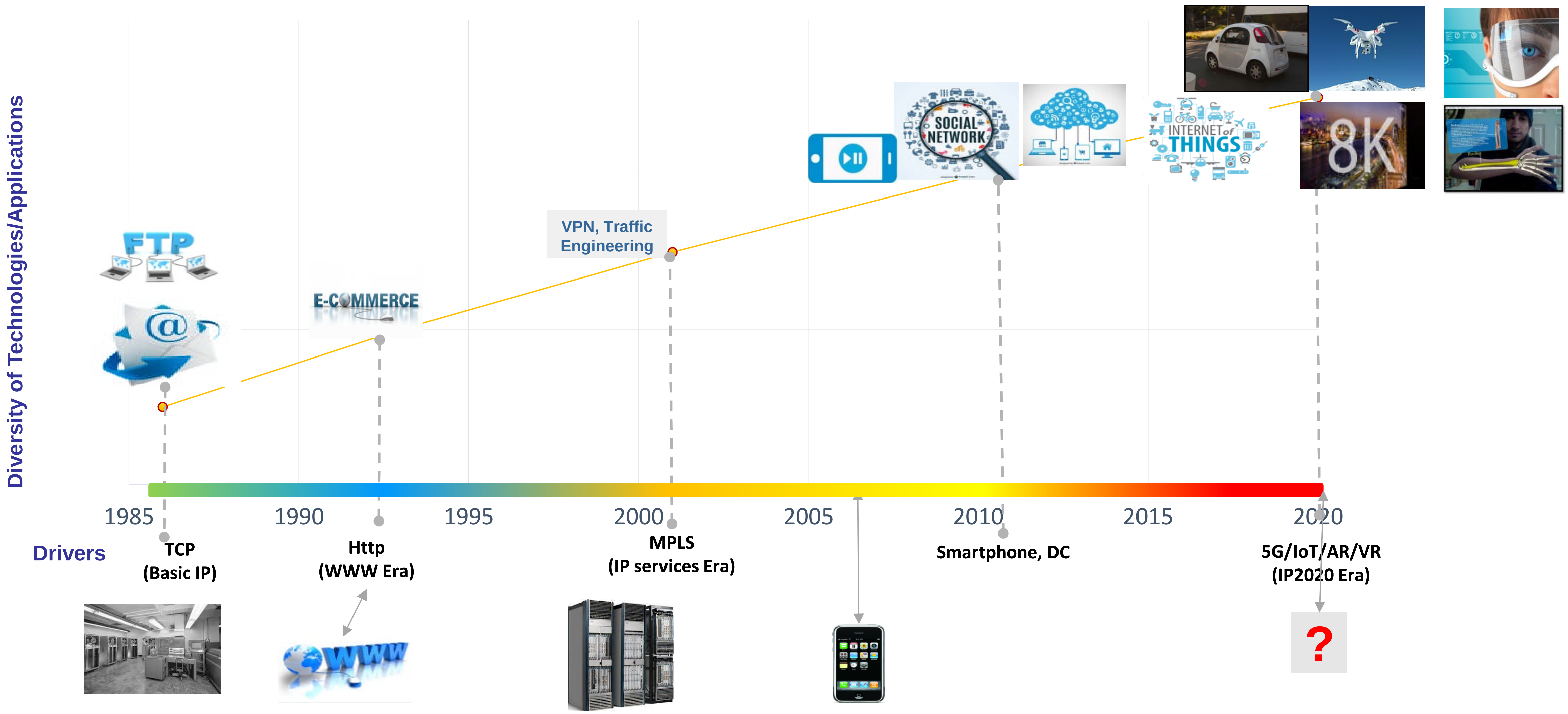
*Source – Physics of the Future – Michi Kaku*

# Predicting Future

- **Near Future (Present – 2030)**
  - Internet Glasses, Contact Lens
  - DriverLess Cars, Four Wall Screens, Flexible Electronic Paper
  - Virtual Worlds
  - Medical Advances – a different healthcare system
- **Mid Century (2030 – 2070)**
  - End of Moore's Law
  - AR/VR in tourism, art, shopping, warfare and not just games
  - Universal Translators, Holograms, 3D
- **Far Future (2070 – 2100)**
  - Mind Over Matter - Mind Reading, Photographing a Dream, Tricoders
  - Climate Control by Humans, Telekinesis – Power of Gods

***Source – Physics of the Future – Michi Kaku***

# Towards 2020: Landmarks in the Internet



# Mobile v/s Fixed

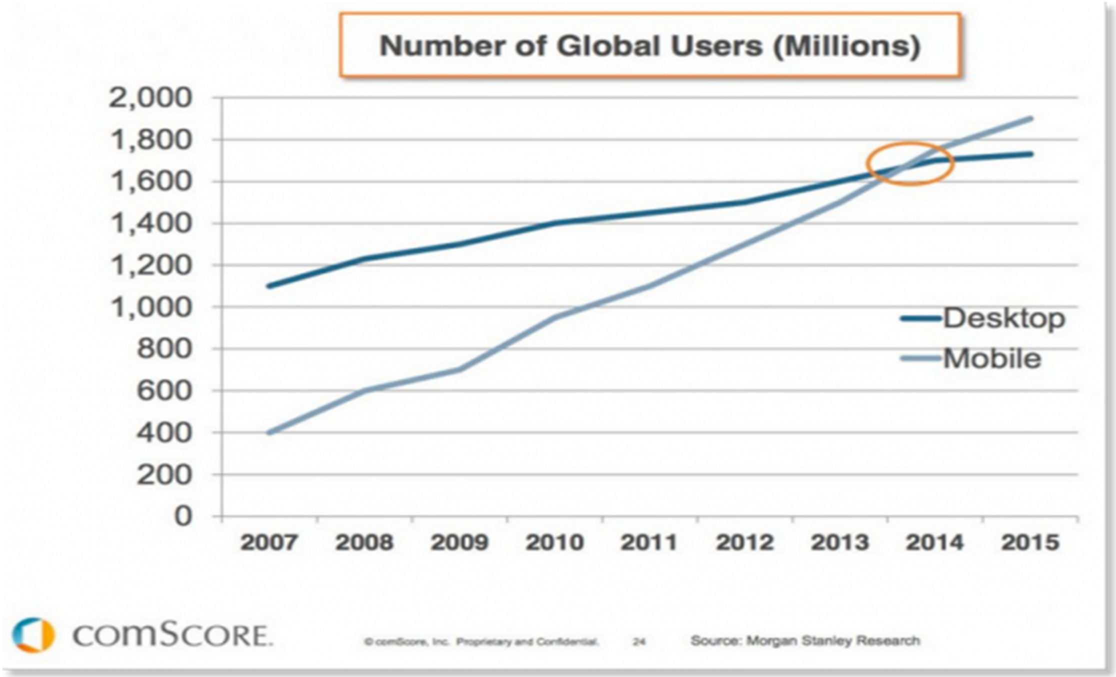
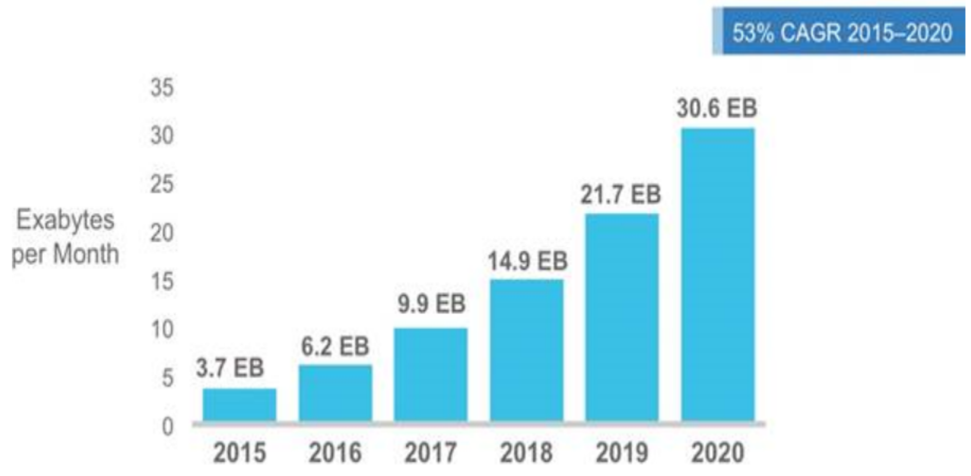


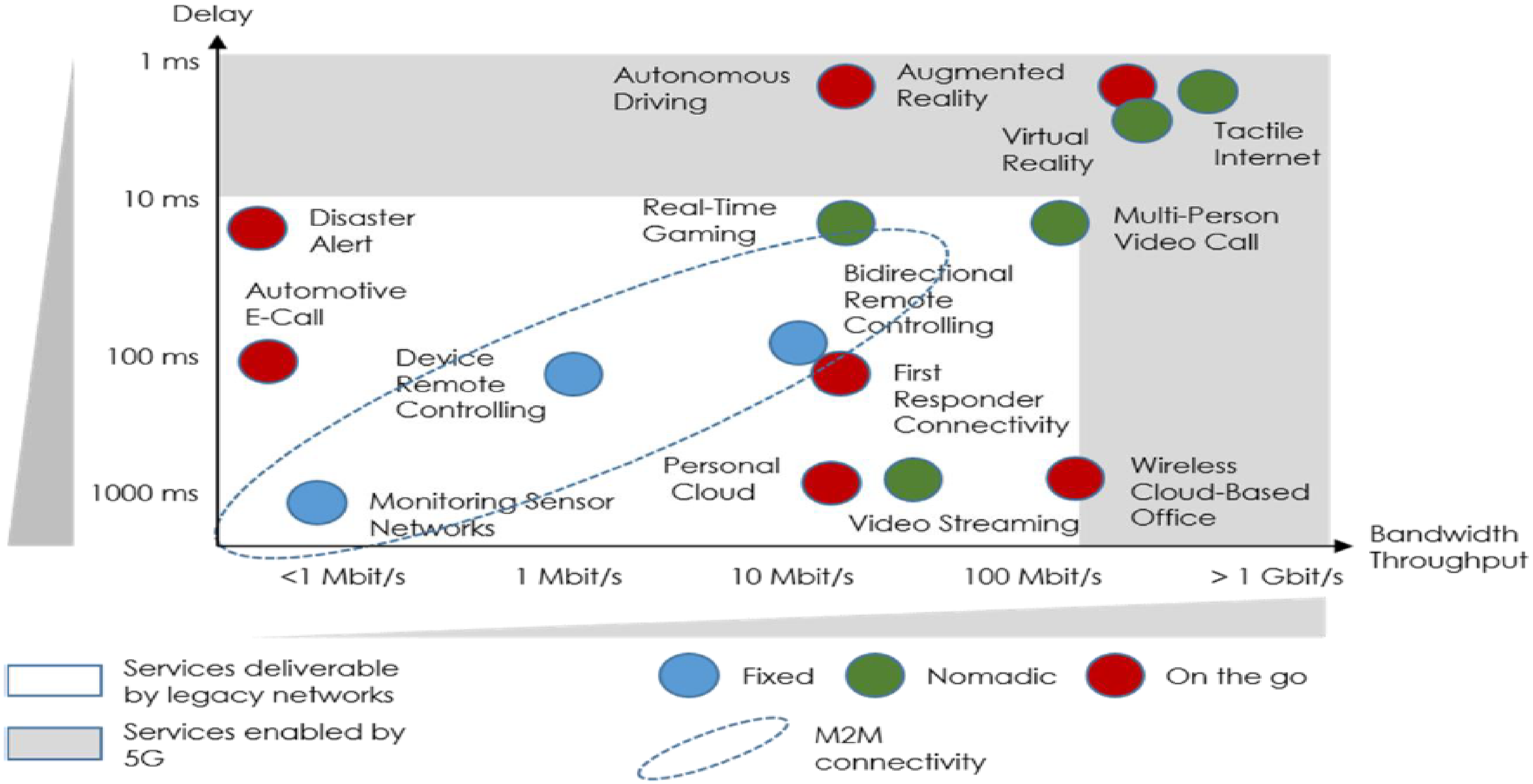

**Figure 2.** Cisco Forecasts 30.6 Exabytes per Month of Mobile Data Traffic by 2020




Source: Cisco VNI Mobile, 2016

- **More than half a billion (563 million) mobile devices and connections were added in 2015**
- **By 2020 there will be 1.5 mobile devices per capita. There will be 11.6 billion mobile-connected devices by 2020, including M2M modules—exceeding the world's projected population at that time (7.8 billion).**
- **Global mobile data traffic grew 74 percent in 2015**
- **Mobile video traffic accounted for 55 percent of total mobile data traffic in 2015**
- **Three-fourths of the world's mobile data traffic will be streaming video by 2020**

# 5G Use Cases in the Year 2020 and Beyond



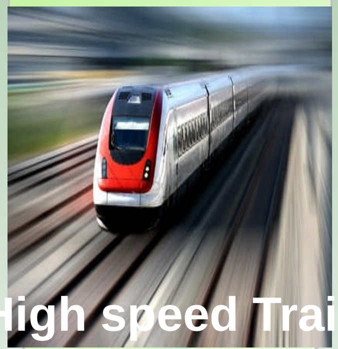

*Source: GSMA, Heavy Reading*

# 5G - Redefining Mobility in Future Networks

| | BW and Speed Throughput | latency | Scale | Session Continuity | Mobility Speed |
|---|---|---|---|---|---|
| 5G | 10 Gps | <1ms | 10-100x | Yes Ubiquitous | 1.5x 500kmh |
| LTE | 1 Gps | 10 ms | X | No seamless sessions | 350kmh |








Various Sources for Data: Huawei – 5G: A technology Vision & 3GPP

# Internet - Today

- **Internet developed for static (non-mobile usecase)**
  - 3GPP usecase for Mobile IP does not provide session continuity at low cost. Lots of replication and session re-establishment
- **Full of Overlays**
  - DC, Enterprise, VPN
- **Lots of Configs and High OPEX**
  - Still in the Era of CLI
  - DataModels thru NetConf/YANG/REST making a dent
- **Scaling is major issue in Data Centers**
  - SP Oversubscription model does not work
  - Need no congestion CLOS networks
  - Most Routing/Switching protocols not built for CLOS with massive scale (links)
- **Latency – Avg RTT ~ 50msec**
- **TCP is main transport**
  - Prohibits mobility (IP address change)
  - Limits useable bandwidth due to congestion algos

# Internet - 2020

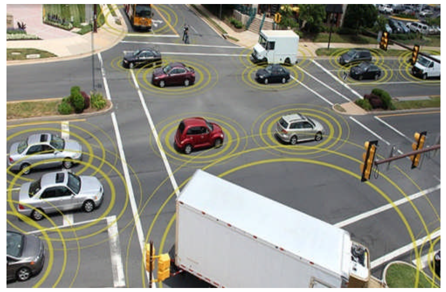
- **Massive Scale**
  - DataCenter scale with Links and CLOS
  - IoT scale with sensors
- **Mobility First**
  - Assume everything that connects to Internet is mobile by 2020
  - Concept of mobility needs to be inbuilt
- **Big Bandwidth To the User**
  - Today – avg user BW < 10GB/month
  - AR/VR would need >5Gbps
  - 4K/8K would need >2G
- **Low Latency**
  - From avg 50 ms RTT to <1ms Latency for sensitive apps
- **Autonomic/Self X**
  - Today - CLI Config to Auto Config - Device to Controller to YANG/REST – transition in place
  - Network Machine Learning for Context, Control, Routing [advances in Streaming Data, Analytics and Network learning algos needed]
- **Context Aware**
  - Not just IP aware. Need context thru ID
  - Move away from Host Centric to Context Centrixc information delivery
- **Secure By Default**

# Networking as a Pillar to New Experiences in 2020

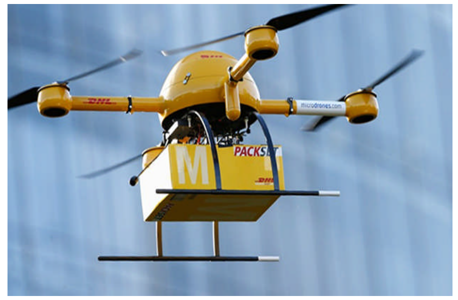
Near Reality Experience


Tele-surgery

Robot Assisted Care



Connected Cars Collision avoidance



Drone delivery


Wearables, sensors, Monitors

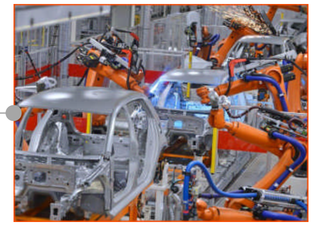
Internet Of Things

Immersive Technologies

Tactile Networks

Smart Mobility

Artificial Intelligence



Industrial Robots

**Always On**

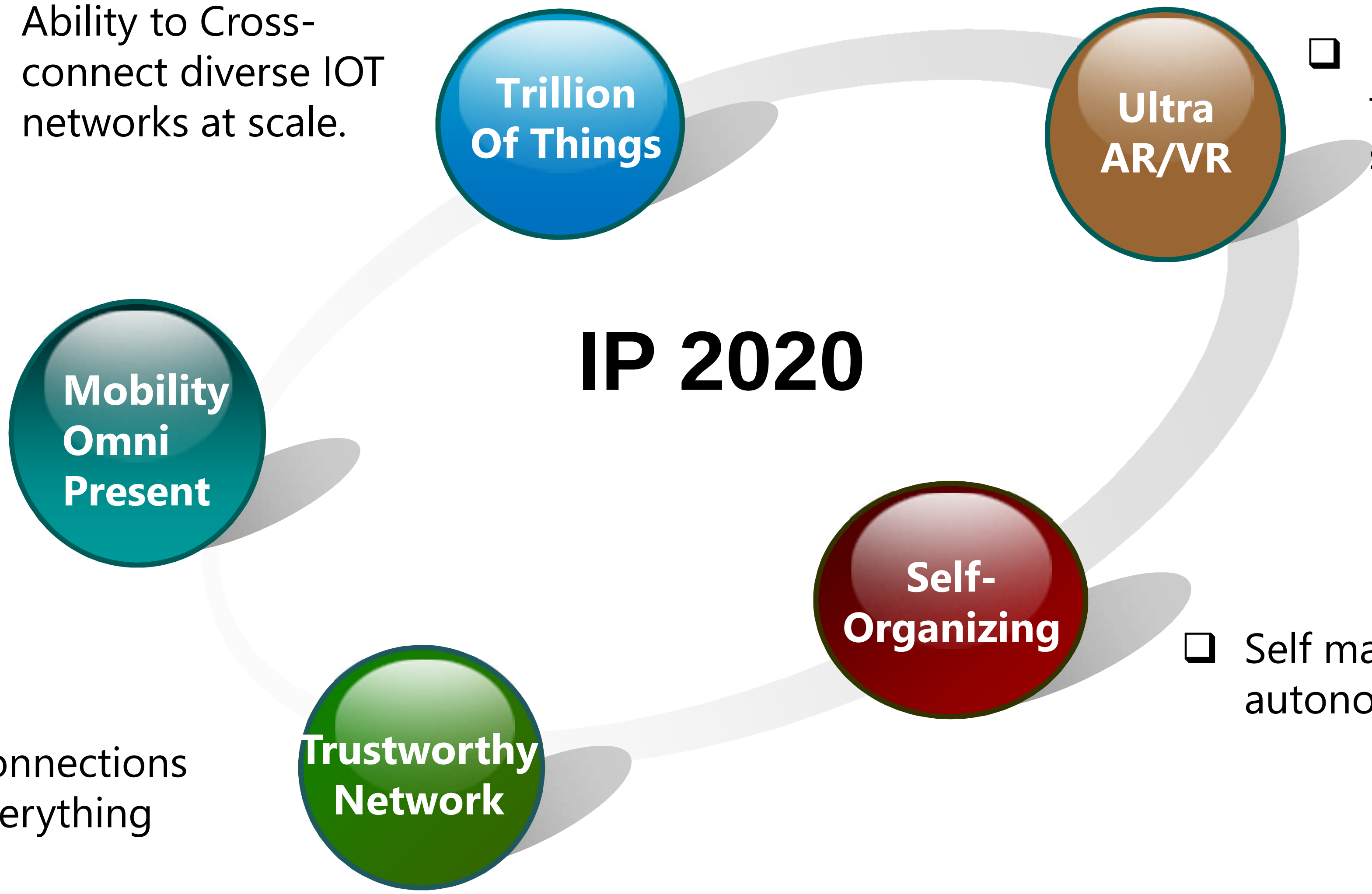
**Pervasive bandwidth**

**Near Zero Latency**

**No perceived data loss**

# What IP 2020 Delivers?

- Ability to Cross-connect diverse IOT networks at scale.
- High-throughput transport delivering super media
- Mobility-Embedded




- Self managing, autonomic networks
- Secure connections across everything

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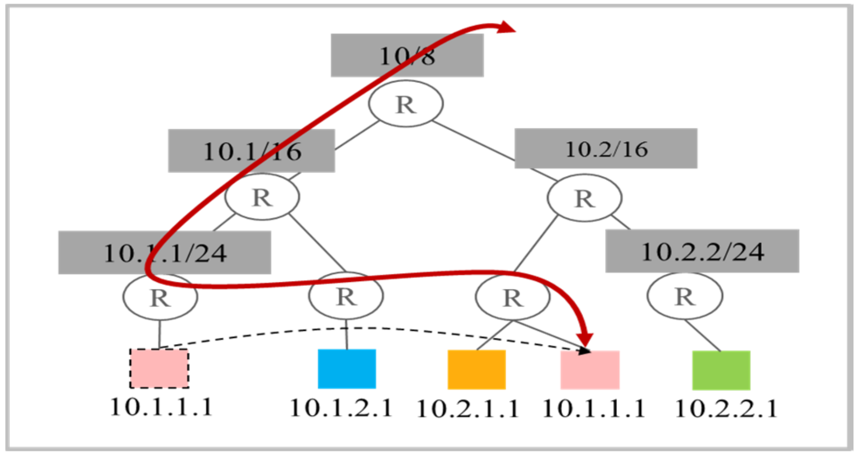
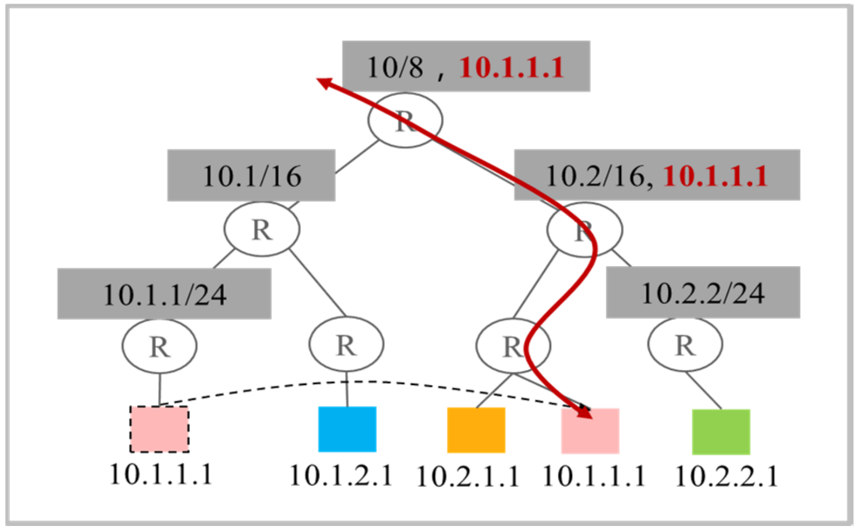
# Mobility in Traditional IP Networks

## IP Mobility must support session continuity all through




**Currently for IP Mobility 2 solutions exist**

### A. Session Preservation via Home Agent Solution

- Home agent communicates with the other end and relays traffic to this end.
- **Causes traffic detours** through the Home Agent
- Added latency degrades user experience
- Deployment of HA drives OpEX higher

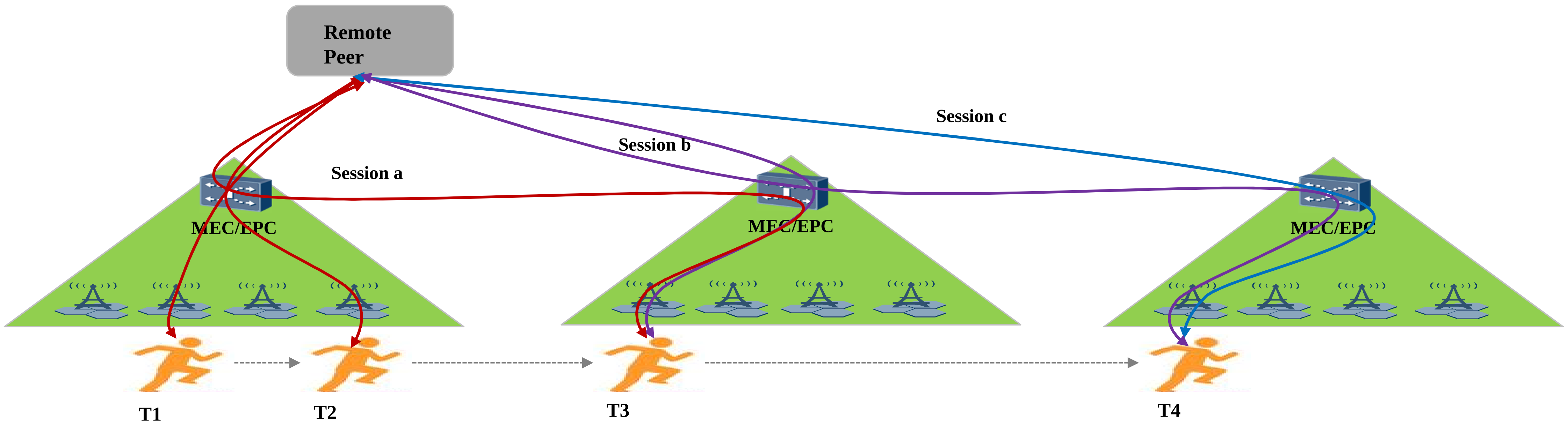
### B. Session Preservation via IP Redistribution Solution

- Update FIB for the entire network to announce new next hop of device IP that moved.
- Optimal Routing but **results in FIB expansion**
- Leads to scalability and slow convergence in the network

**Challenge: None of the IP Mobility approaches satisfies 5G scale and applications requirements**

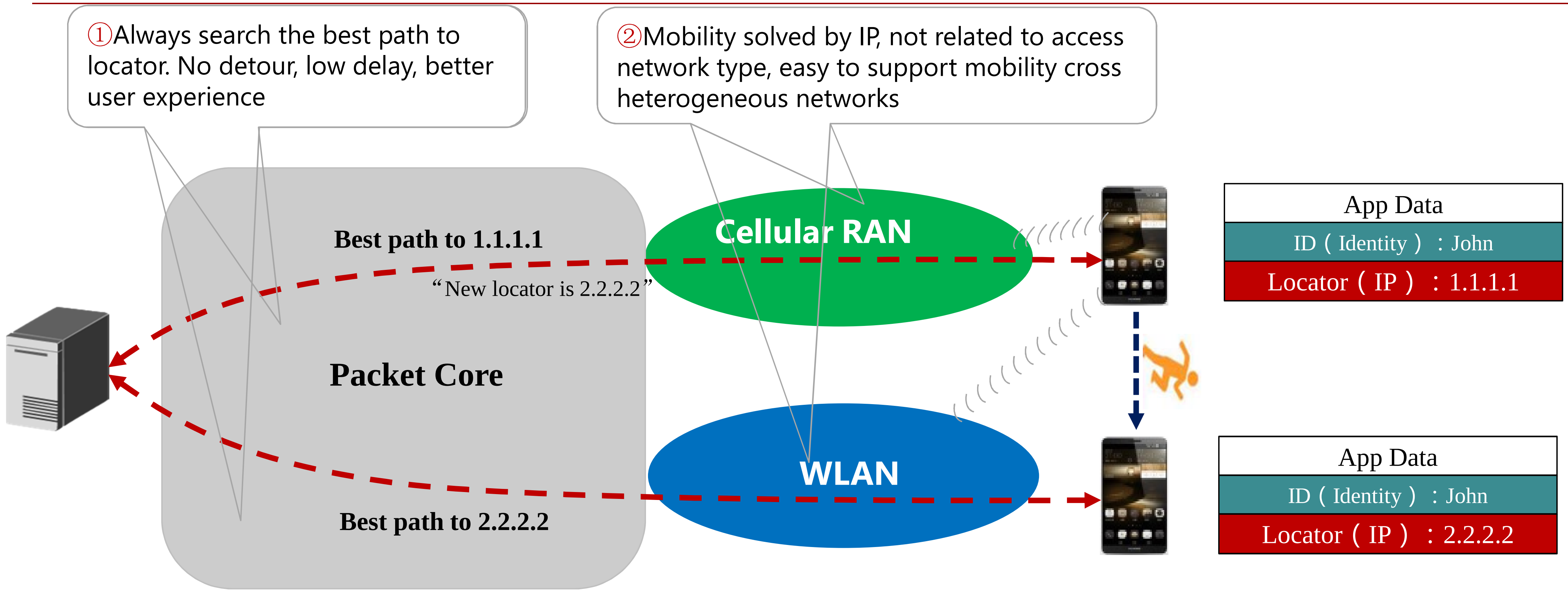
# Mobility in EPC and Distributed Mobility Management

**DMM: old sessions still go through old gateways, and new sessions go through new gateways**



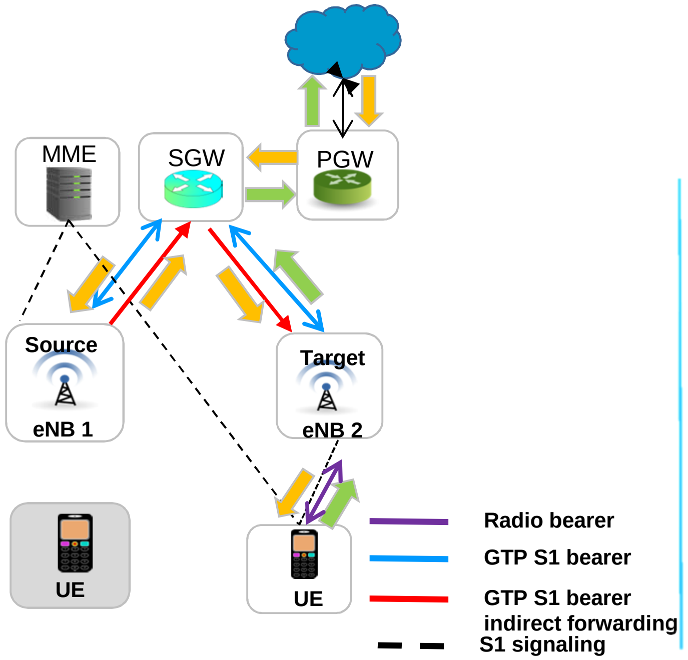

- **Centralized Anchor:** EPC works as a centralized mobility anchor, which causes traffic detour and thus the traffic latency is longer.
- **DMM:** It improves traffic latency for new sessions, but does not help old sessions, since old sessions still go through old gateways.
- **Unnecessary Mobility:** Applications without need of session continuity still go to the mobility management process

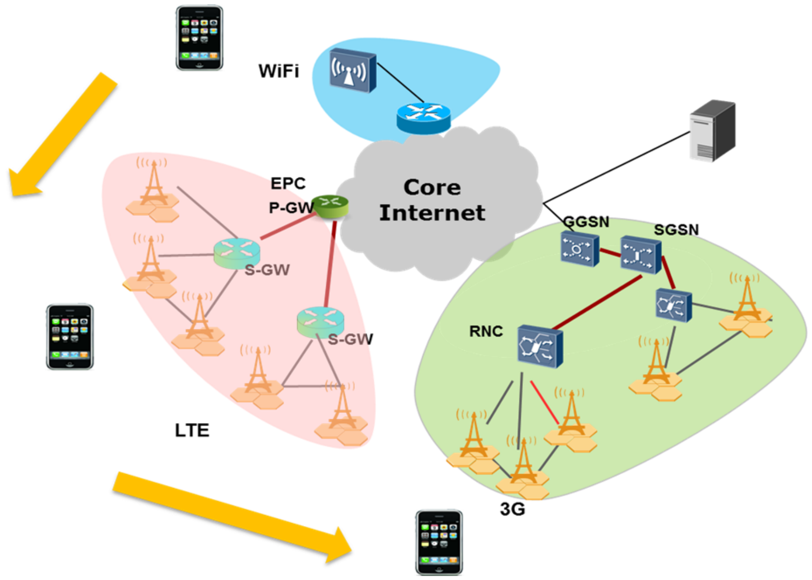
# ID Plays a Central Role in Mobility

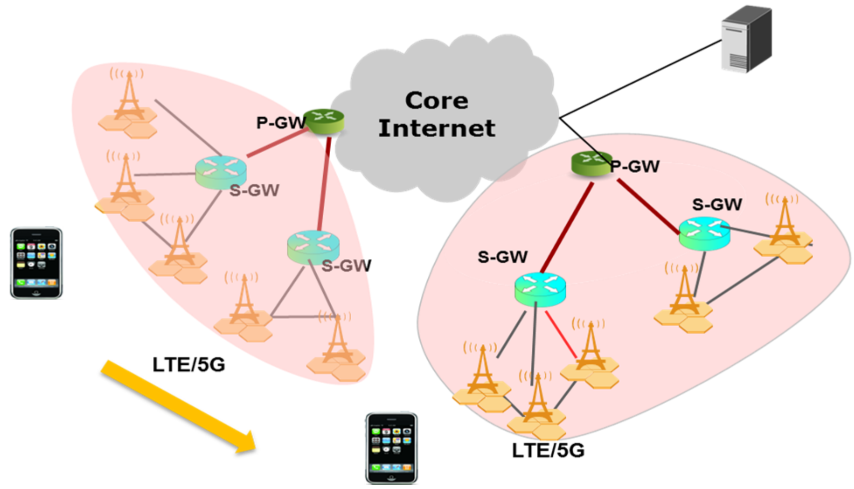



- **No Detour to EPC Anchor: - Thus End-to-End latency is minimized and the user will have a better experience.**
- **Mobility is independent of the access network type and there is no need for mobility gateways or agents.**

# 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.

# 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<br>Use of IPv6<br>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.<br>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. |

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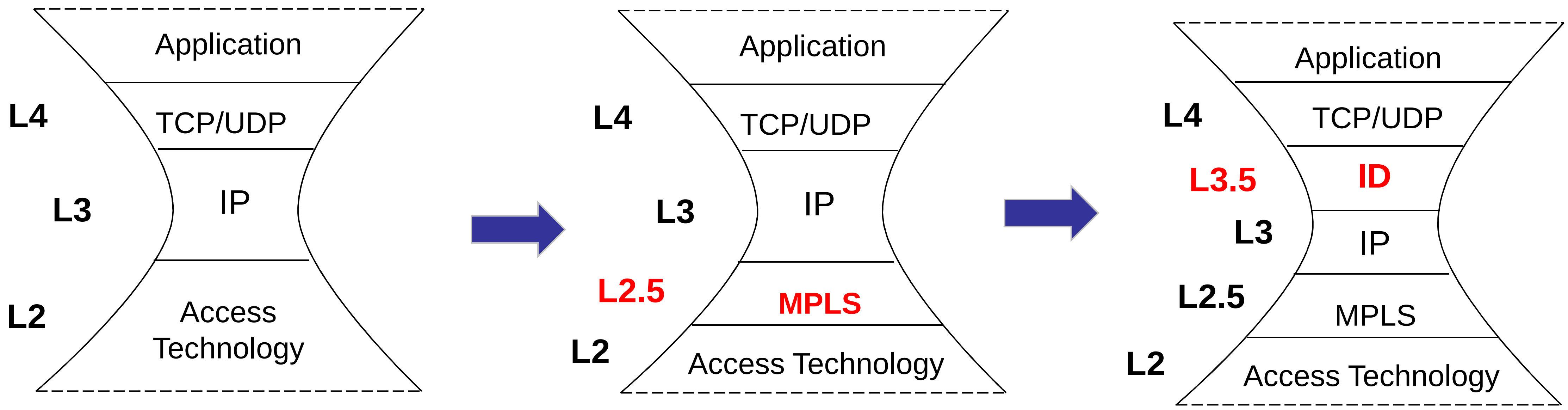
# ID-Oriented Networking Protocol Stack

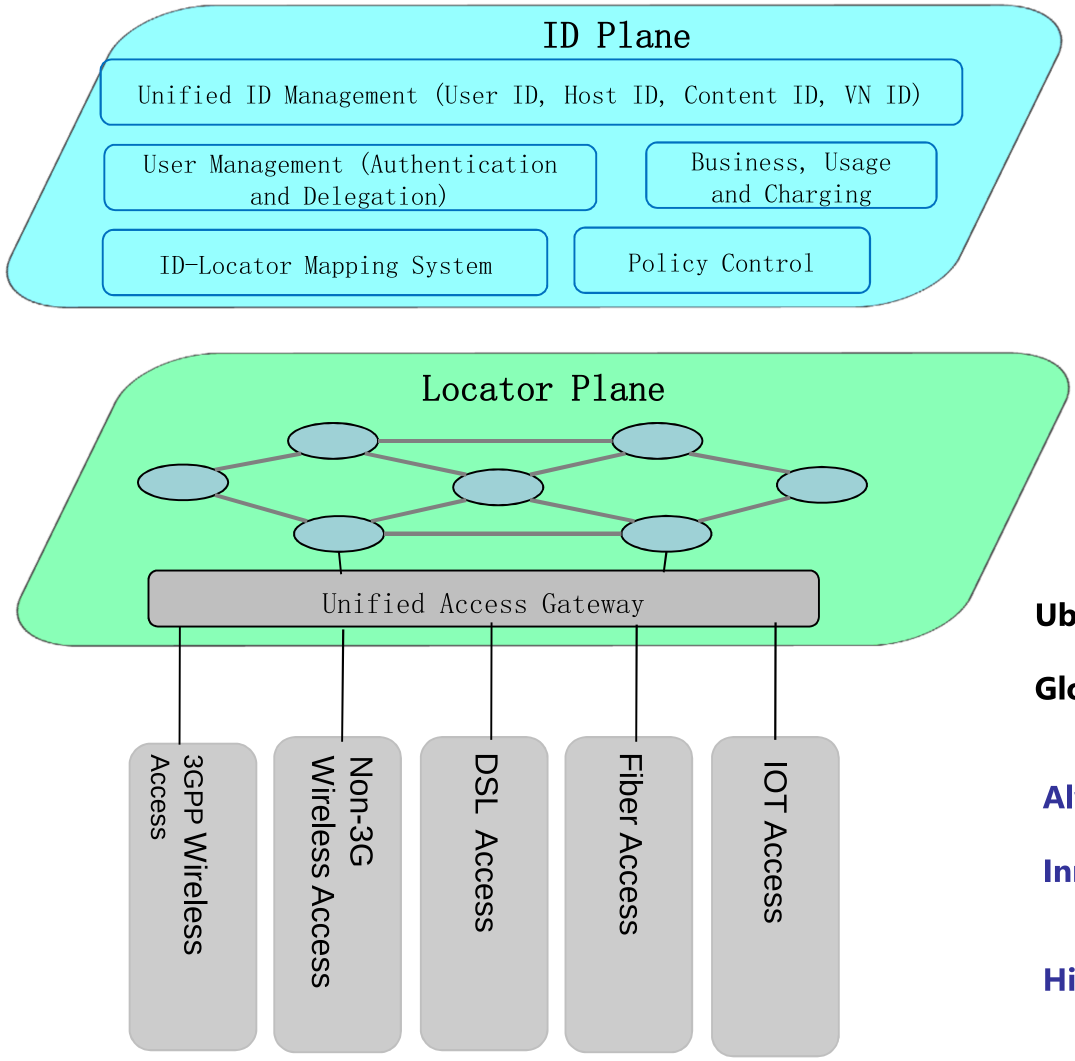



Current IP: Two Meanings of IP Addresses

1) Identity: What it is (Identity)
2) Location: Where it is (Location)

- ID for universal mobility and global reachability
- Locator for routing: address aggregation and longest prefix matching
- ID can represent user, host, content, and virtual network
- Locator varies from a place to another while ID keeps unchanged

# Splitting Network Plane into Two Layers: IP and ID




| Main Functions | Owners/Operators |
|---|---|
| • Access-agnostic authentication and delegation<br>• Access-agnostic mobility management<br>• Uniform ID management for users, hosts, contents and virtual networks<br>• Differentiation in traffic management and scheduling for different classes of services | • Telecom Operator<br>• ISP<br>• Virtual Network Operator<br>• Public Service Provider (for example, IANA/DNS/ID Management) |

| Main Functions | Owners/Operators |
|---|---|
| • A high-bandwidth, congestion-free, heterogeneous substrate network infrastructure<br>• Routing on best-prefix matching on locators | • Infrastructure provider or operator (base station, fiber)<br>• Telecom Operator |

**Ubiquitous Mobility**
- **Network is agnostic to the access type: 3G/4G/5G, WiFi, or IoT access**

**Global Reachability**
- **Everything, has a unique ID.**
- **Reachable at anytime from anywhere in the Internet**

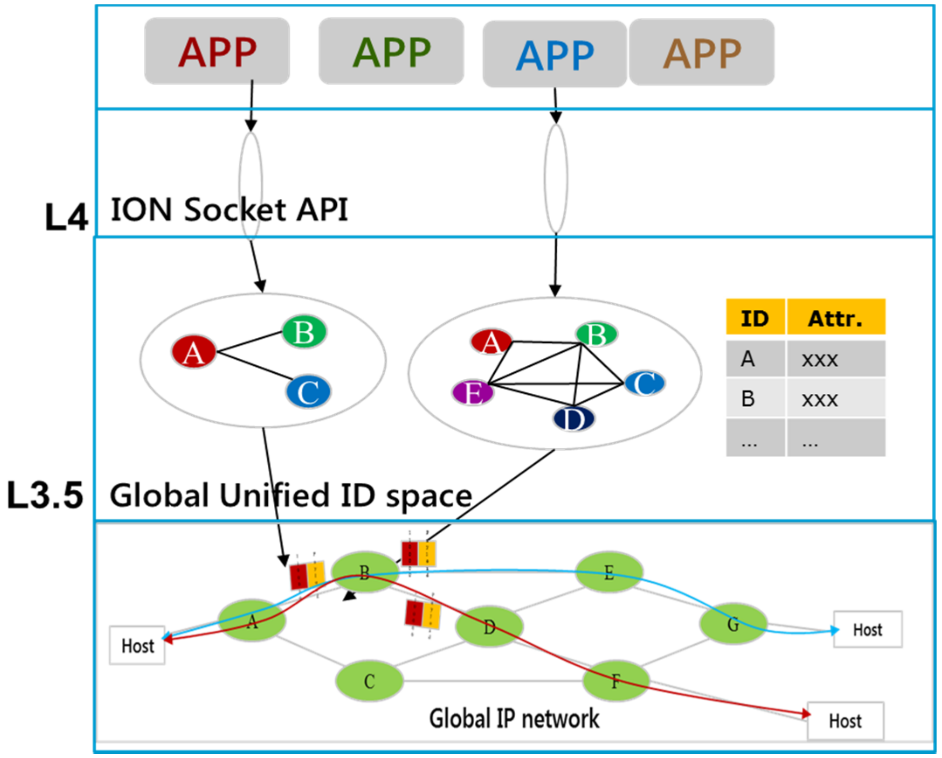
**Always On**
- **Addressable, being able to send/receive messages without setting up a tunnel**

**Innovation Acceleration**
- **Locator plane works as a transport layer, while ID plane works as a service layer**
- **New services are developed on top of ID without changing the underlying locator plane.**

**High scalability**
- **No need to maintain GTP-like tunnels to (wireless) hosts.**
- **It is scalable as high as 100 billions of things for IOT.**

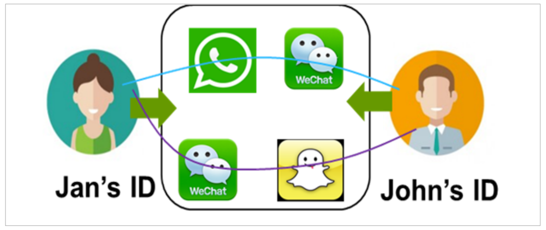
# ID Oriented Networks : Application Model

## Enables Everything through an ID Aware Model

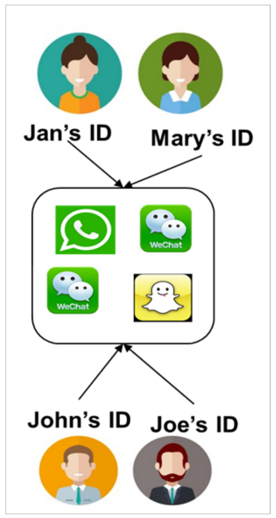



### ION Sockets

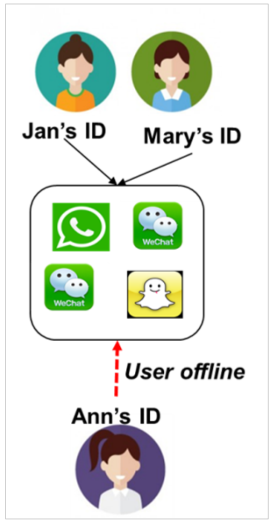
- Applications connect with ID based sockets
- IP layer locates source and destination ID accurately and sets up path




1. Point to Point




2. P2MP & MP2MP




3. Asynchronous

### Easier To Manage Communication Relationships with IDs

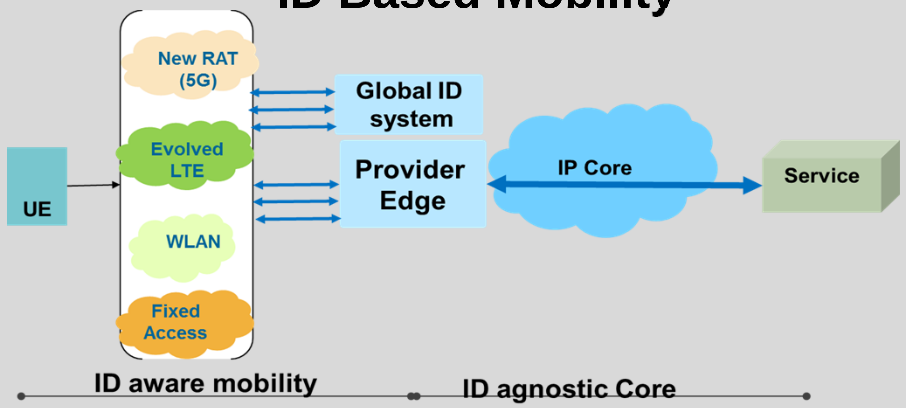
1. **Point to Point**
   - Single ID For Multiple Applications
   - Cross-application Channels
2. **Group Communication with ID**
   - Both P2MP and MP2MP
   - Same as (1)
3. **Support Active/Passive Comm.**
   - Synchronous when ID is online
   - Asynchronous when offline.

### Unified ID Space

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

# ID Unlocks New Opportunities Beyond Mobility

## ID Based Mobility




- ❑ **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**

## Benefits and Opportunities from Layer 3.5

- ❑ **L3.5 Communication**
  - **P2P Communications without servers**
  - **Cross-silo communication possible**
  - **ID based Group-communication (PIM free)**
- ❑ **Accelerated applications deployment over L3.5**
  - **Network/Topology change agnostic**
  - **Focus on business logic not network**
- ❑ **Refined L3.5 Edges**
  - **Fine grained ID aware TE, Policy, LBs**
  - **ID based End to End Security**

# ID-Oriented Networking: Summary

- **Simpler Mobility Management**
  - Without Mobility Anchor E.G. EPC Or Home Agent
- **Uniform Interconnection Of Everything –**
  - IoT, Hosts, Contents & Users
- **New Business Opportunities**
  - With Accelerated Application Development
- **Backward Compatibility**
  - For Applications Based On IP Sockets With Marginal Changes
- **Research Areas :**
  - ID Sockets
  - Security Policies for ID Networks
  - Global ID Mapping System
  - Group/Multicast ID definition and distribution
  - ID based ICN

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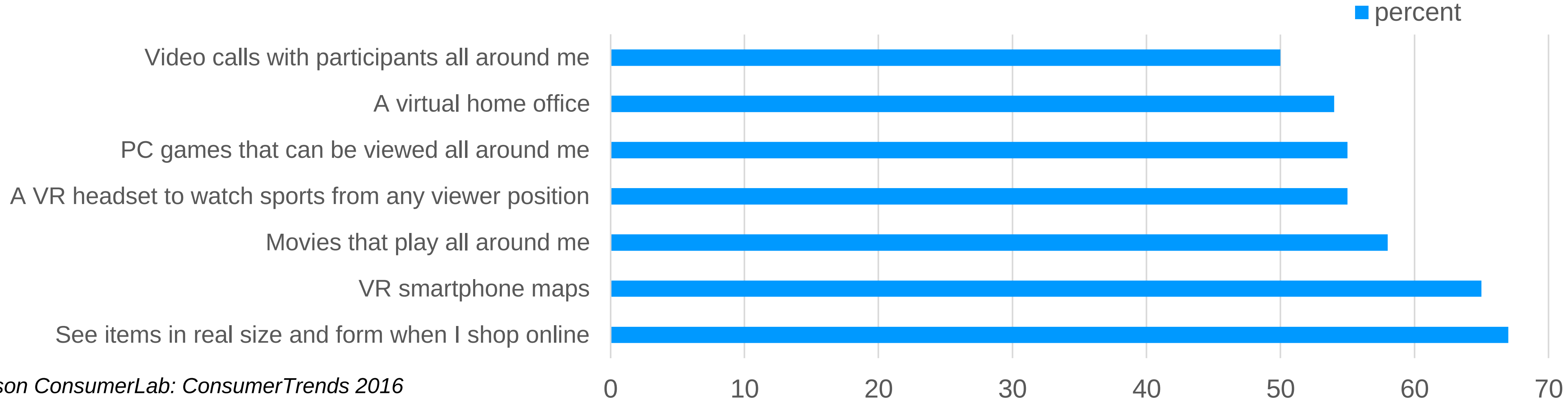
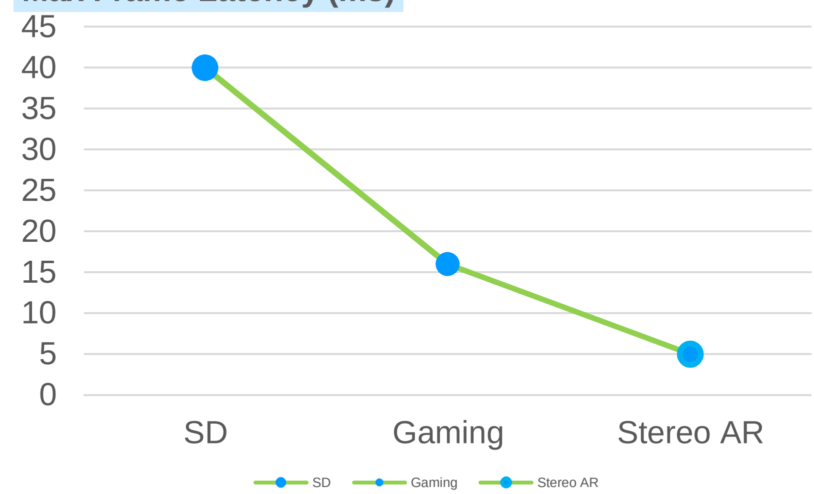
# Recent Transport Trends – Immersive Experience

**Consumer survey on VR services**




*Source: Ericsson ConsumerLab: ConsumerTrends 2016*

**Max Frame Latency (ms)**

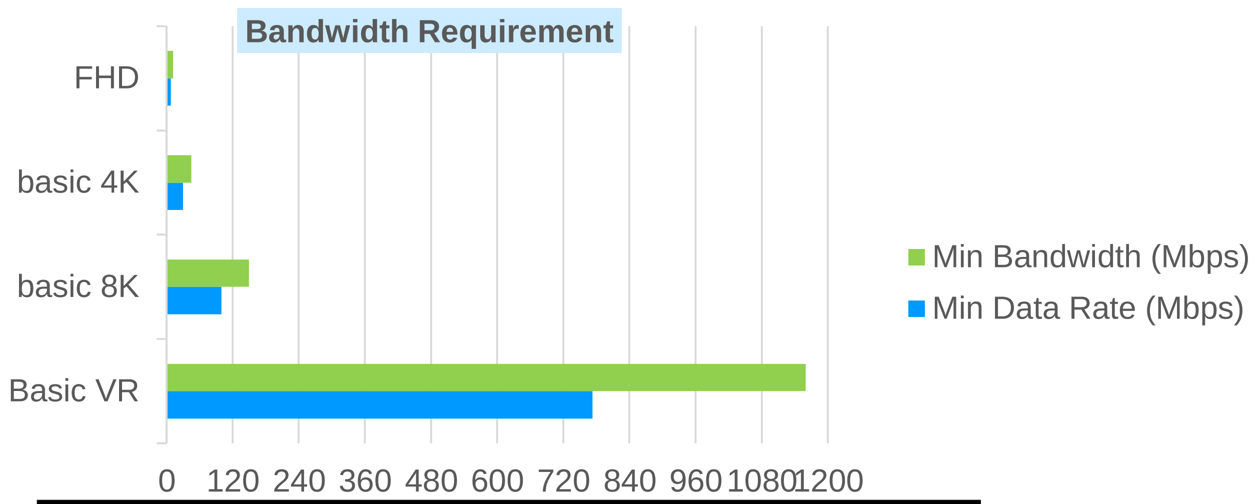


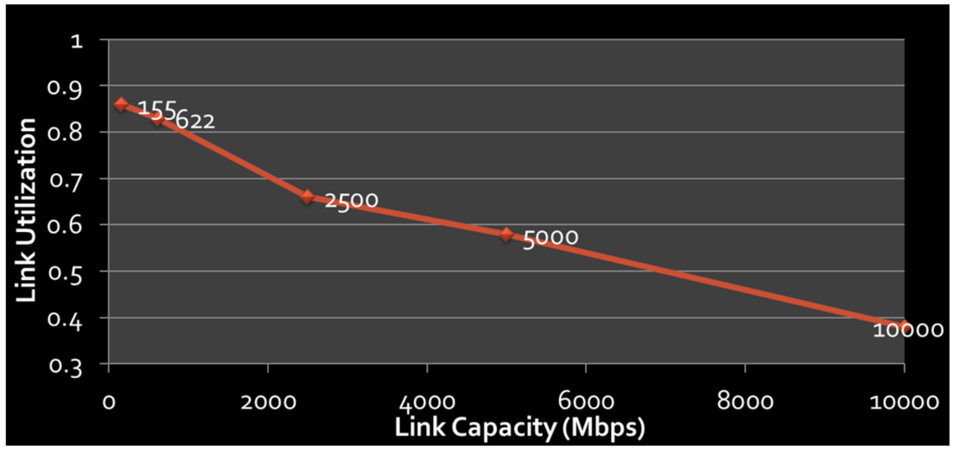

**VR User Experience Challenges**

- Frame Latency – Decouples from virtual world
- Causes disorientation

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

# Available bandwidth is not used well




**Increase in physical bandwidth doesn't help TCP throughput**

### Bitrate for a video format

bits per pixel X resolution X frame rate

### Conventional TCP Throughput

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

### Example - Packet Loss Consequences

*Bandwidth* = 100 Mbps; *Delay* = 60 ms, *packet loss rate* 1/10000,
Actual throughput: 23 Mbps

- ❑ **User experience is more related to the session throughput.**
- ❑ **The session throughput growth does not go up with the bandwidth growth at the same scale**
- ❑ **The session throughput increase can provide the better investment return for carrier**

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

# Why the Application Throughput Matters?

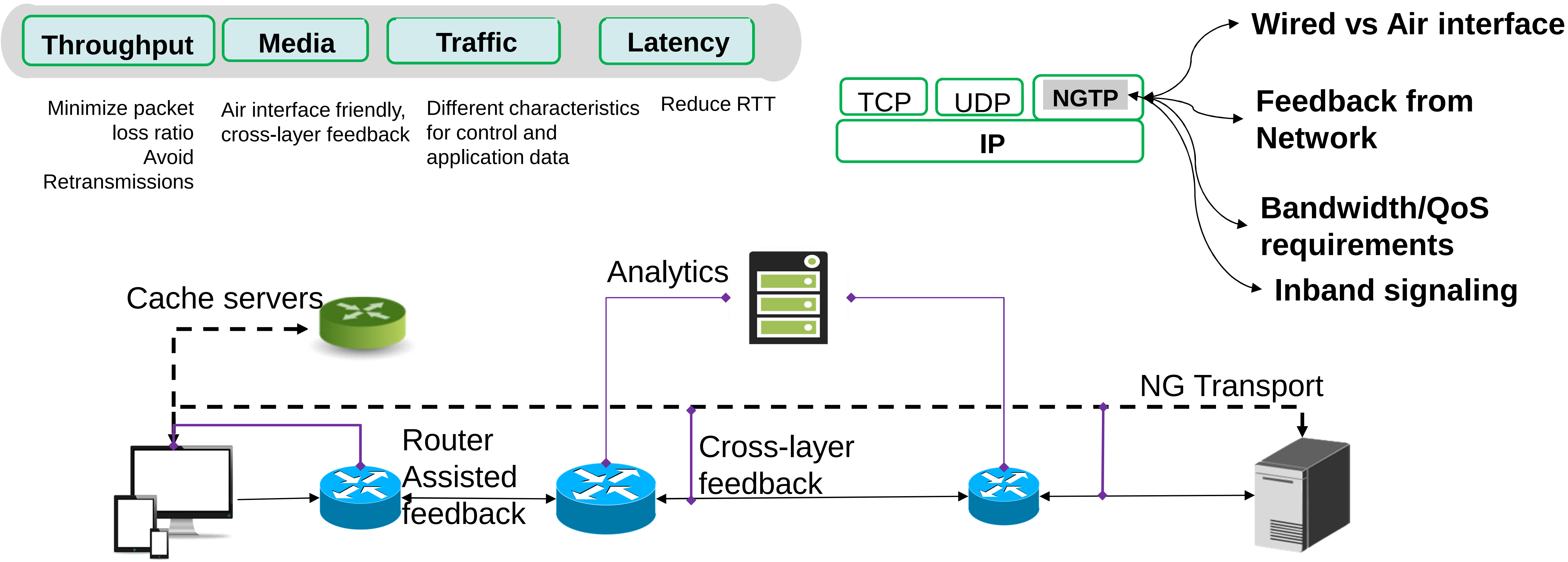
## It’s all about User Experience!

| 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 | 50/60 | 100/120 | 25/30 | 50/60 | 100/120 | 50/60 | 100/120 | 100/120 |
| Color depth | 8 | 8 | 8 | 8 | 10 | 12 | 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 | 30 | 50 | 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 |

# State Of the Art - Standardized solutions

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

# Transmission Media Aware Transport Efficiency



# 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.**

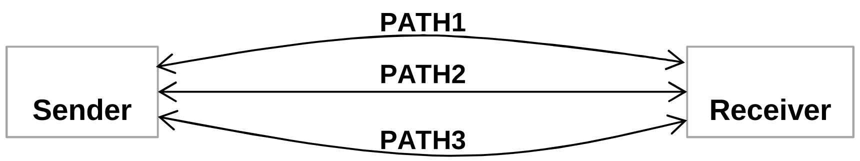
**The real congestion is determined by the available BW of the bottleneck. How to get that info?**

**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

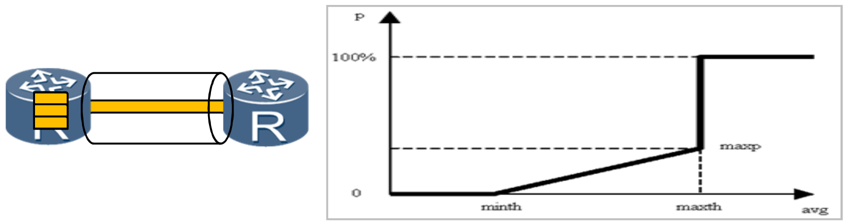
**The problem of current mutli-stream transport:** MPTCP, which is mainly focused on reliability and improving throughput moderately, lack efficient algorithms in high throughput .

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




## NGAQM

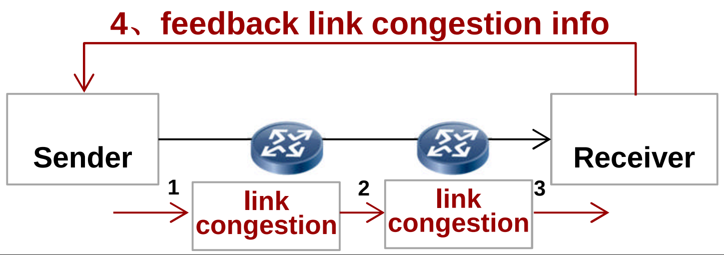
**Key point:** 1) VR needs low latency & high throughput. So we are researching on a new AQM Algorithm with small buffer instead of large buffer. 2) Part of port utilization is converted to queue, instead of physical buffer.




NGAQM---virtual port queue

## ECN+

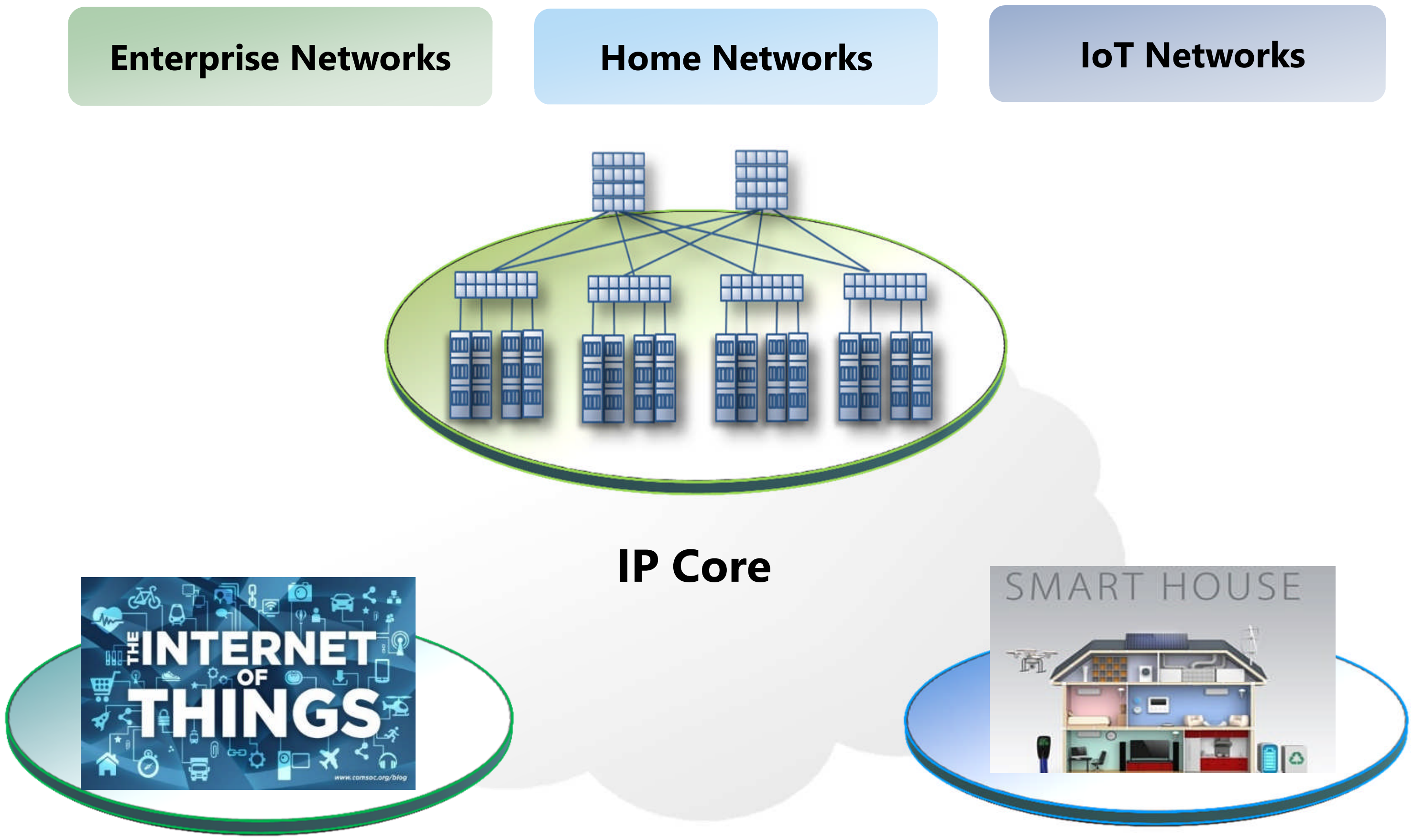
**Key point：** network layer and transport layer interact with each other. The network devices feedback the link idle rate and congestion info, and then transport layer increase cwnd in one step based on the link idle rate, which can improve the throughput and meet the low delay requirement.



# Agenda

- Introduction
- Ubiquitous Mobility
- ID-Oriented Networking
- New Transport
- Self-X Networking
- Security and Trustworthy Network
- Concluding Remarks

# Why Intelligent Networking?




**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**

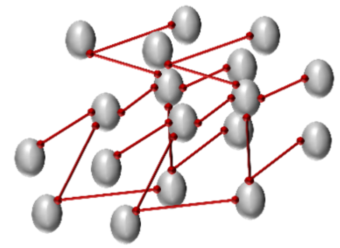
# Self-Organization and Automation Issues in Enterprise and IoT Networks


## Enterprise

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

- Tedious Manual Planning (Error prone)
- Minimize Human Intervention in Network Design & Operations

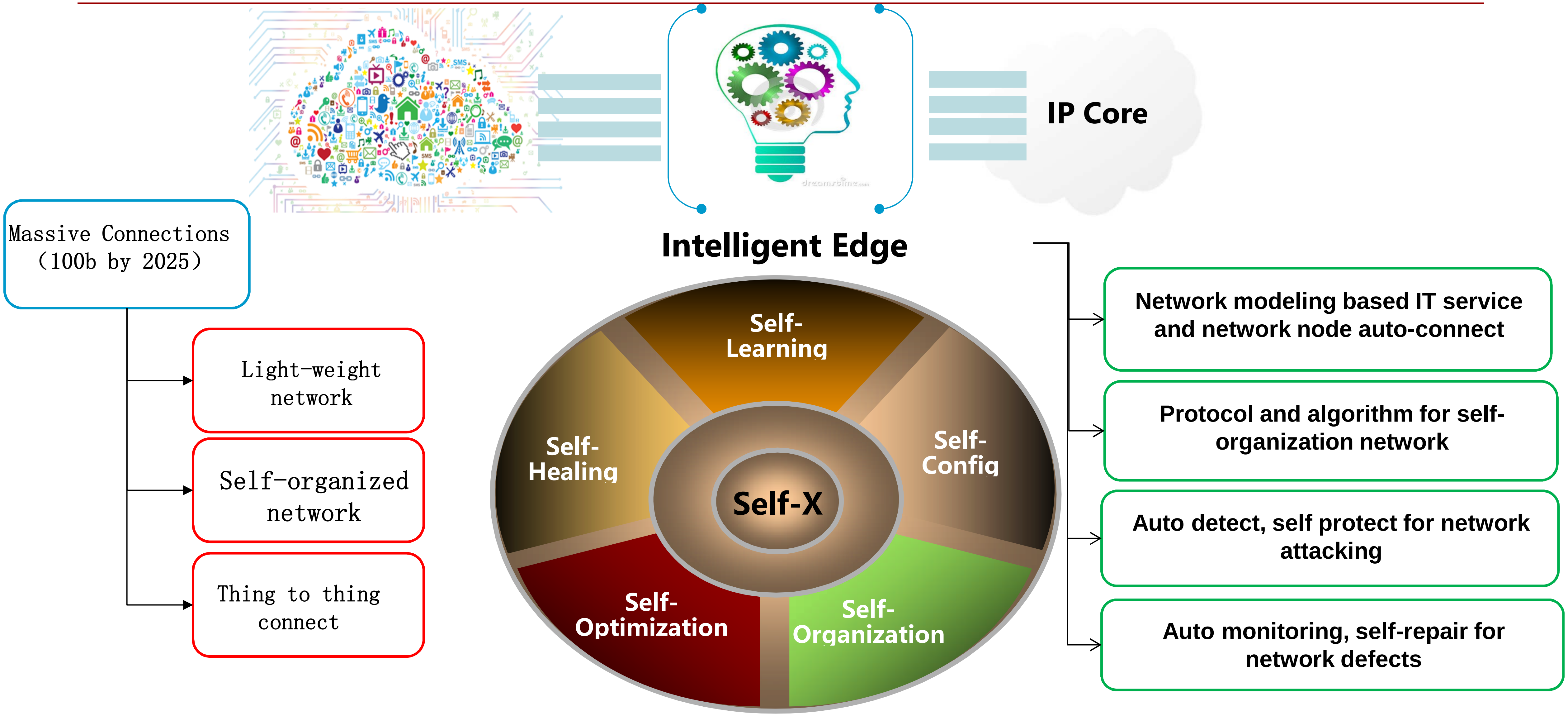
## IoT Networks



| | |
|---|---|
| Resource Adaptiveness | Properties differ w/ RATs |
| Energy Sensitive | Light weight routing |
| Various Sensor types | Multiple sensors deliver a service |
| Environmental Changes | Sporadic traffic bursts |
| Volatile Topology | Static configs won't work |

- Can Not Operate With Conventional Techniques
- Address Massive Scale And Variations, Environmental Constraints

# Self-X Network for Intelligent Edge



# State of Network

## Today

- **Auto-Discovery/Registration**
  - Proprietary, DNS, MsgBus
- **Auto Config**
  - DHCP, NetConf/YANG at Device Level
  - NetConf/YANG/REST Network Model
- **Self Healing Devices/Networks**
  - Routing Protocols – self healing
  - Fault Detection – Needs work
  - Fault Isolation – Network Policy settings
- **Autonomic Networks**
  - Defined in IETF
  - Deployment Infancy

## 2020

- **Autonomic IoT Networks**
  - At massive scale
- **Network Analytics**
  - Day Zero Analytics
  - New Security traffic anomaly detection
- **Network Machine Learning for SelfX networks**
- **SDN/Controller Based Network Level config**
  - Performance Routing
  - PCEP

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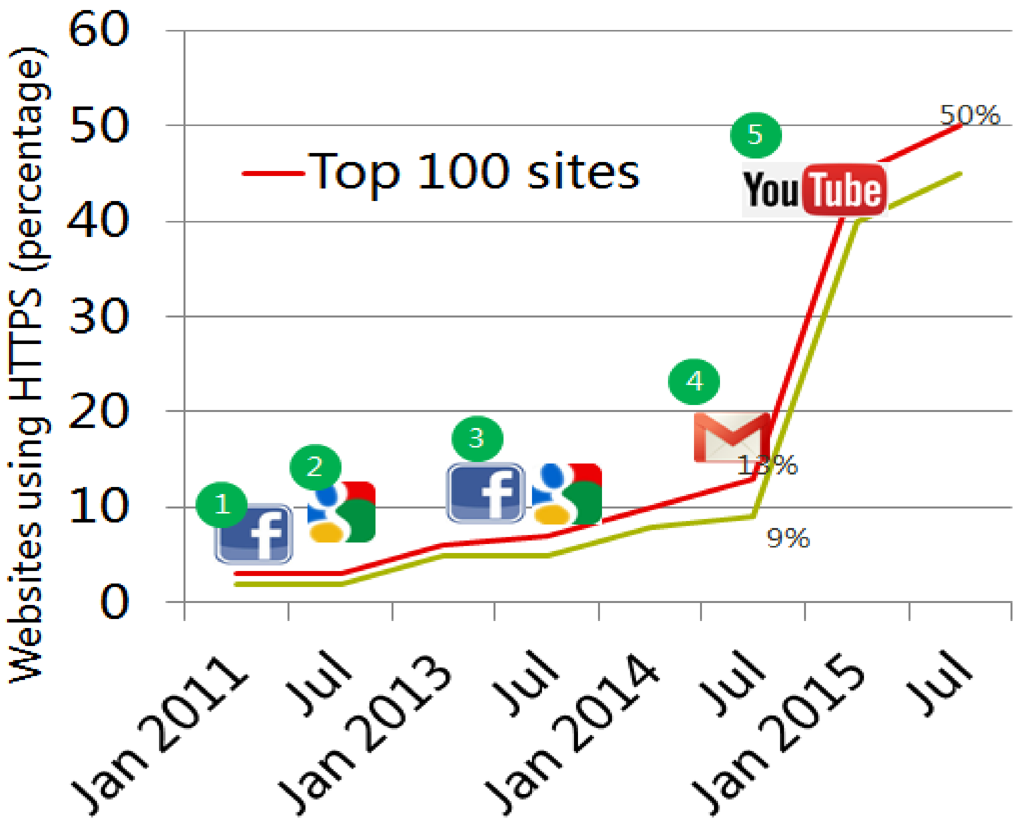
# Security and Encrypted Traffic in Higher Demand



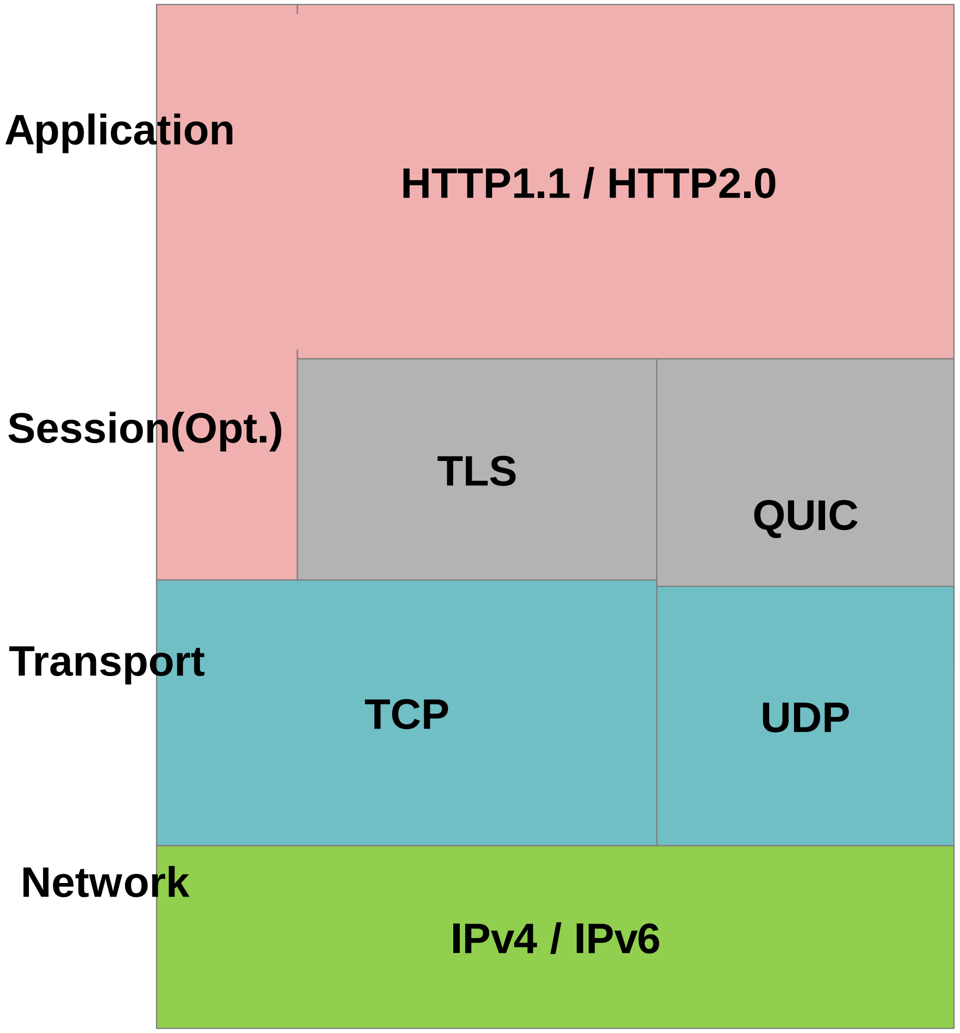

Data sourced from httparchive.org. Top 100 and million sites as ranked by Alexa

1. **2011: Facebook adds an option for secure login**
2. **2011: Google Search provides secure search**
3. **2013: Facebook, Google Search are encrypted**
4. **2014: Gmail is encrypted**
5. **2014: YouTube traffic is encrypted**

- Internet traffic encryption are implemented and provided by Google, FB, Twitter, Yahoo and Snapchat, which accounts for 45-50% (source from VDF, Mozilla)
- Content providers are increasingly planning to provide encryption for their traffic, for example, Netflix and BBC are testing their networks for encryption.
- **By 2020, 80% of all Internet Traffic will be encrypted**

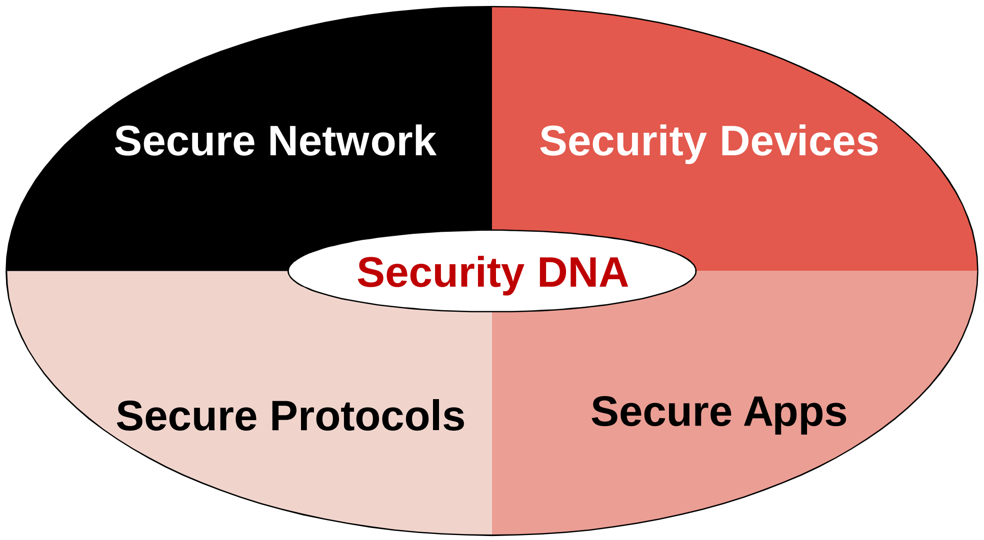
**Encrypted traffic is growing at a faster pace after 2011. Now it accounts for 45-50% of the total Internet traffic, and it continues to grow.**

# Security should be built as part of Network DNA




**Security is more than encryption. It should prevent**

- Malicious users
- Malicious traffic flows
- Route hijacks



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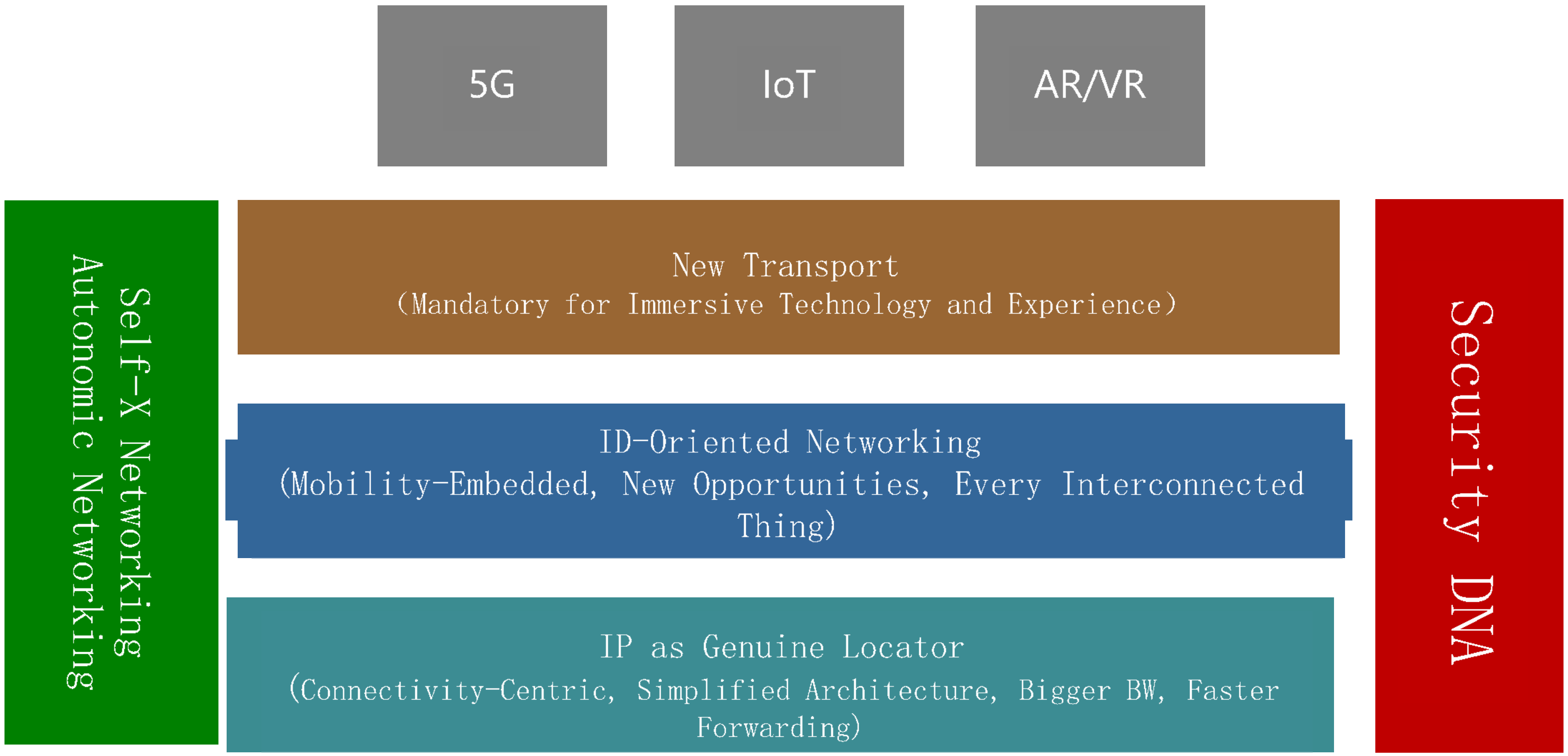
# Protocols for IP 2020: A Summary



# Thank you

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