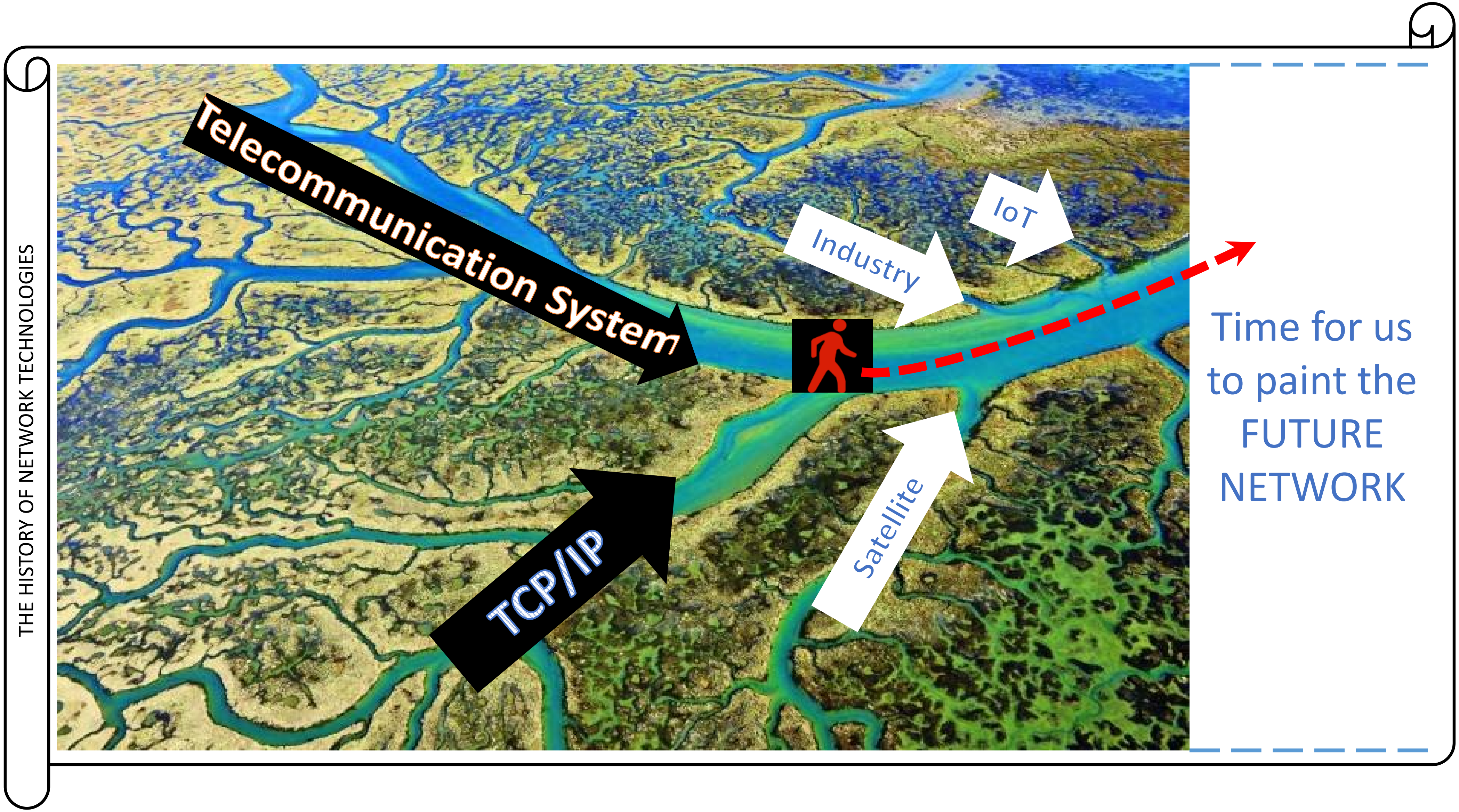
New IP Networking for Network 2030

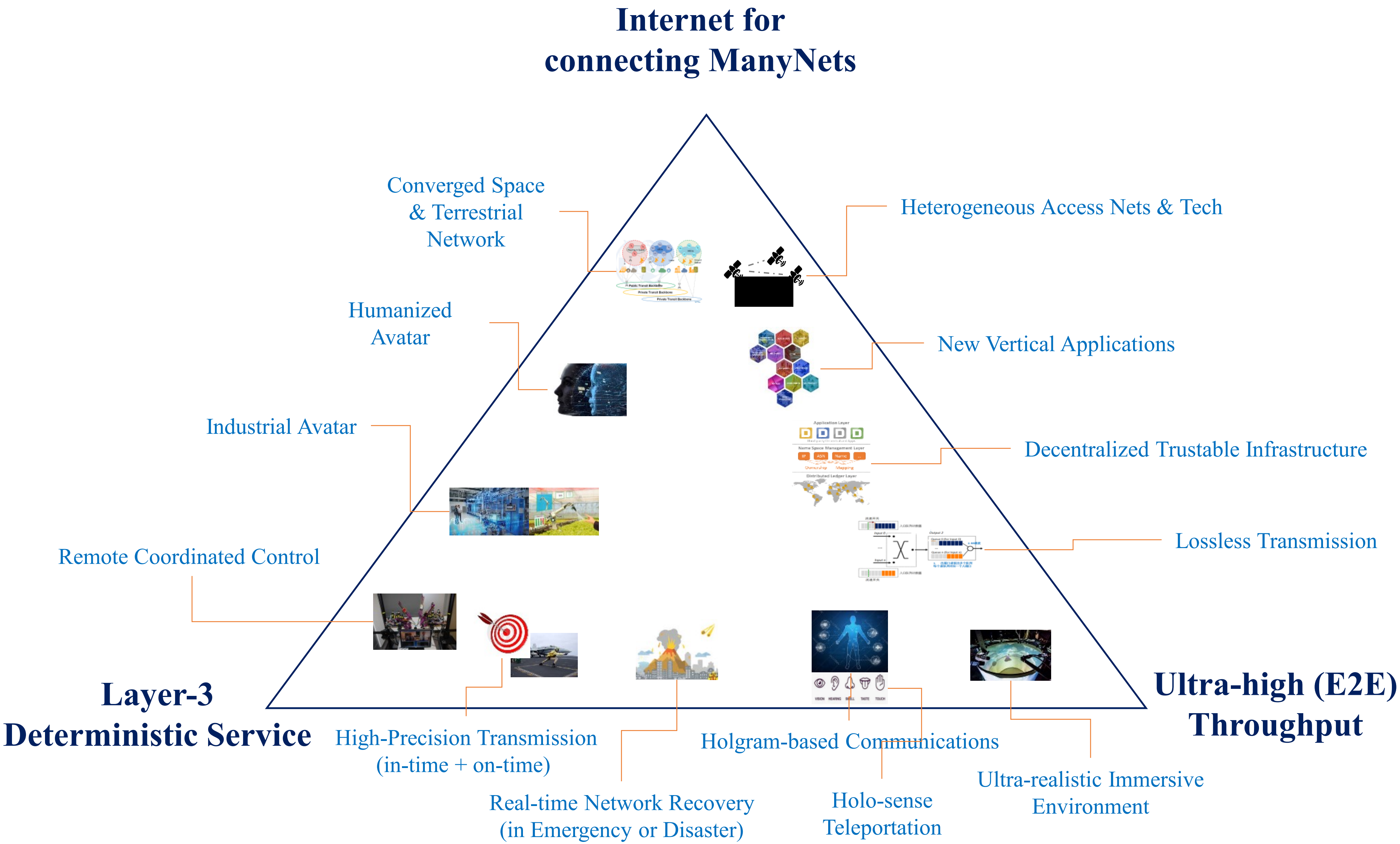
Sheng Jiang

The Merging Trend between Telecommunication and TCP/IP



[1] Yilang Peng, Dance of River, Bo Wu Magzine,No. 5, 2012. Online: http://www.dili360.com/nh/article/p5350c3da1dce024.htm

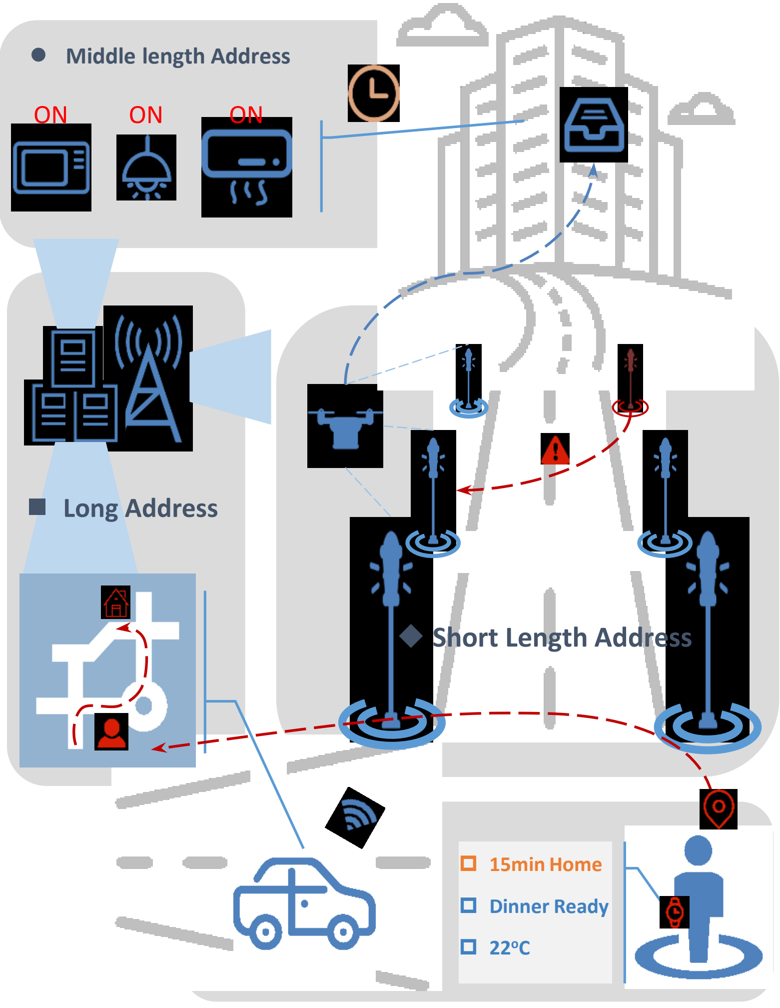
Future Network Scenarios & Requirements of Network 2030



New IP

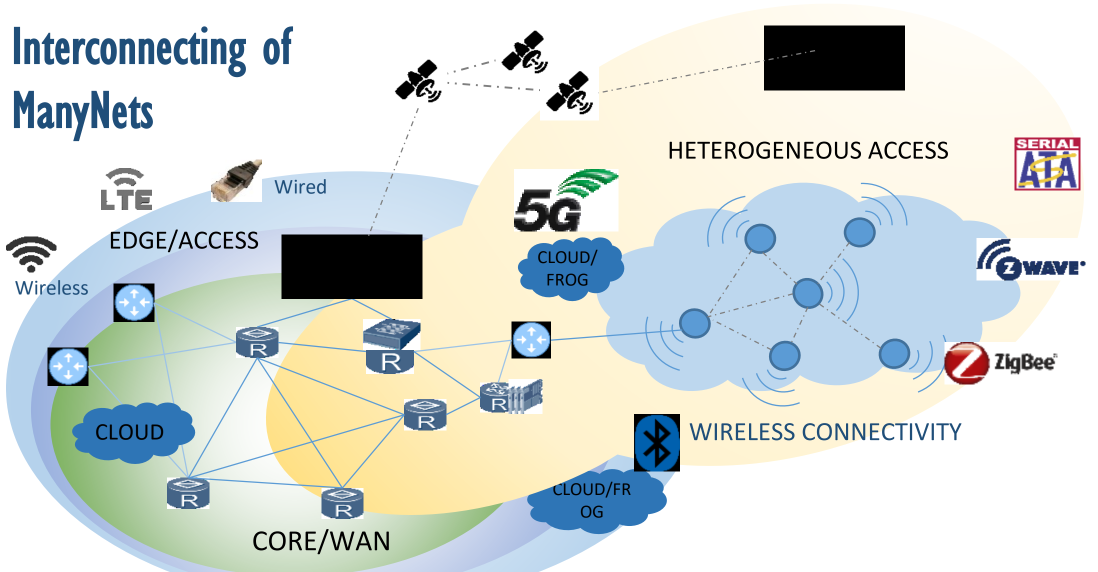
New IP is IP+, universal IP, flexible IP

Interconnecting of Everythings



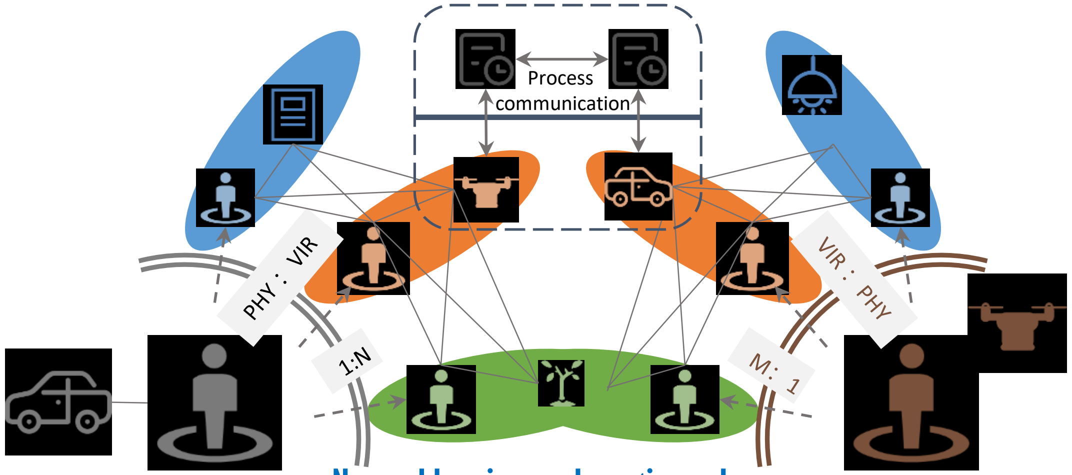
Flex valuable length address

Interconnecting of ManyNets



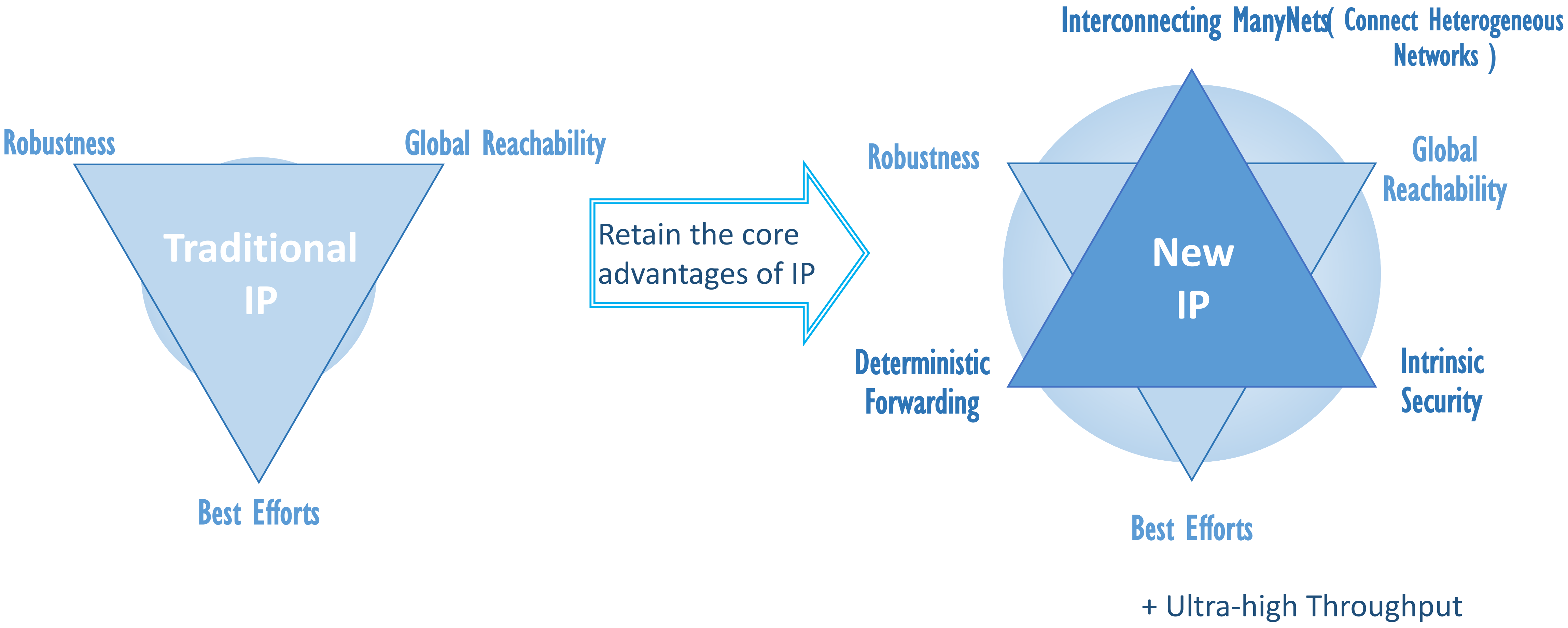
Heterogeneous networks and addresses

Integration of physical and virtual world

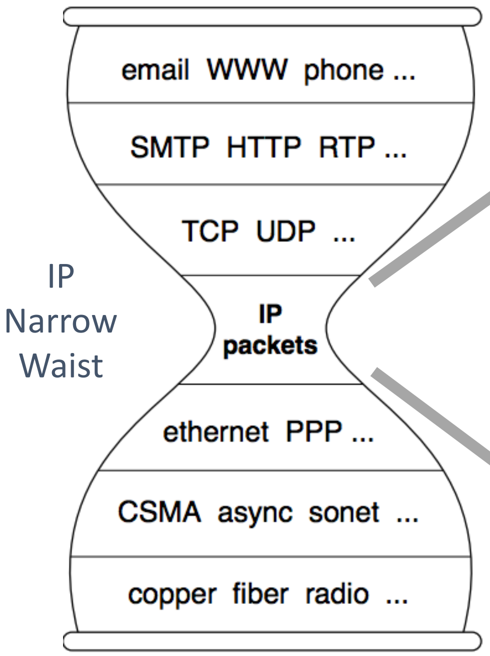


New addressing and routing scheme

New IP: the Innovation Technology to Meet the Requirements of Network 2030



Inherit the Successful Gene of IP and Go Further



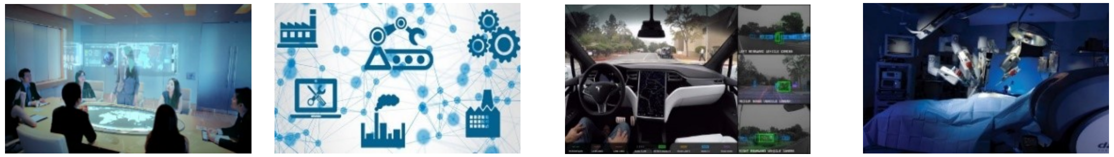
Best-effort can hardly provide reliability QoS and support strict requirements from complex application.

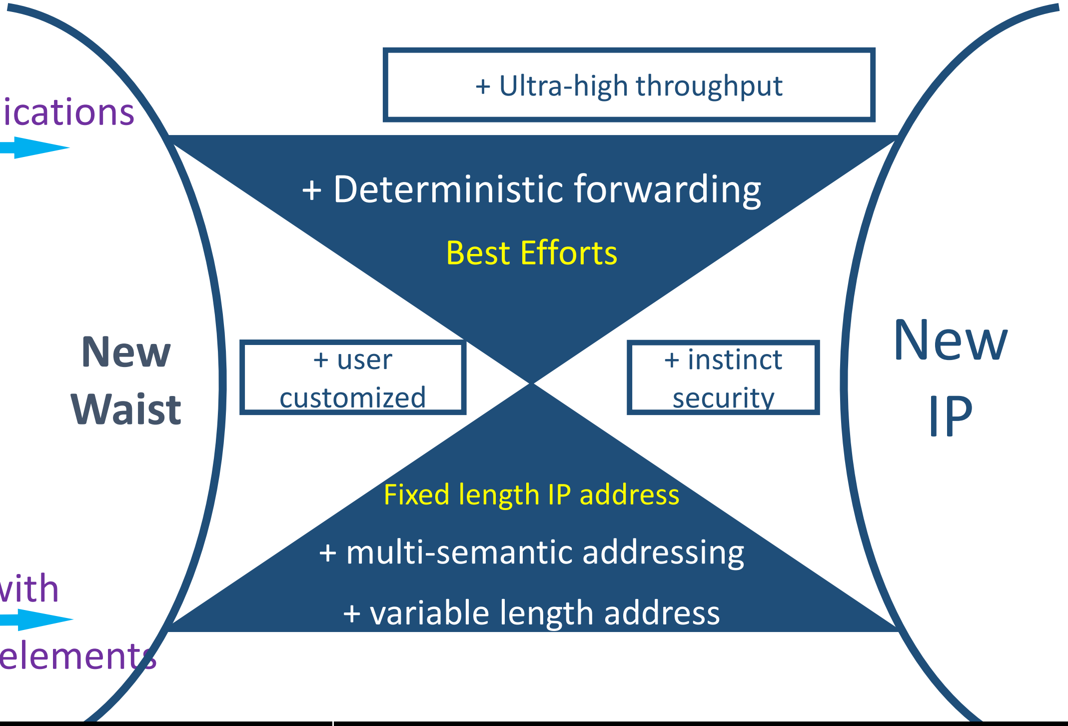
By remaining the advantages of statistical multiplexing and compatibility from traditional IP network, New IP aims to upgrade the fundamental capabilities then let the network become the incubator of the future services.

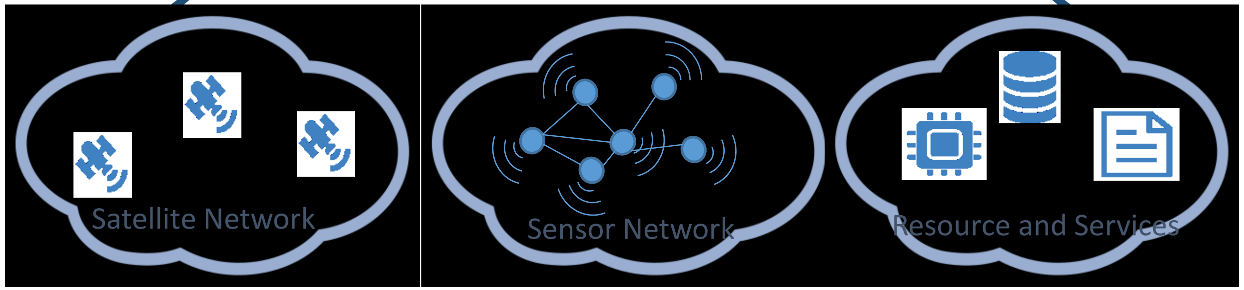
Only provide connectivity. All the elements will be mapped into equal-length digital address which is hard to support diversity services.

Support more applications

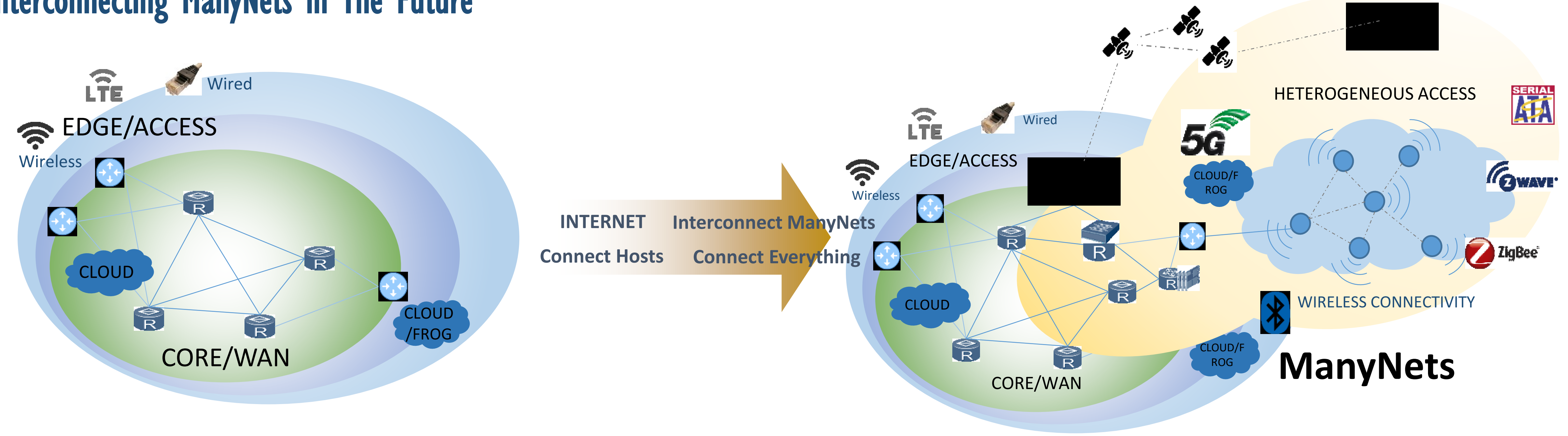
Compatible with diversity network elements



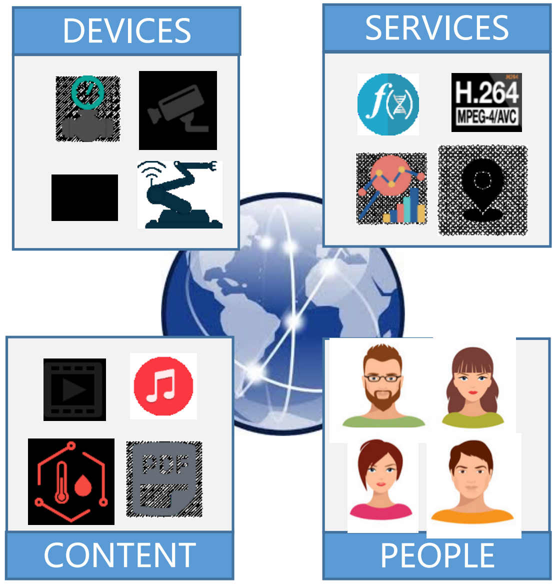




Interconnecting ManyNets in The Future



Ubiquitously connect massive of physical entities, such as smart terminals, sensors, wearables, vehicles, and industrial control devices



The popularization of in-network computing and AI technology will let the service resources, such as such as micro-services, processes, and functions, become virtual communication entities

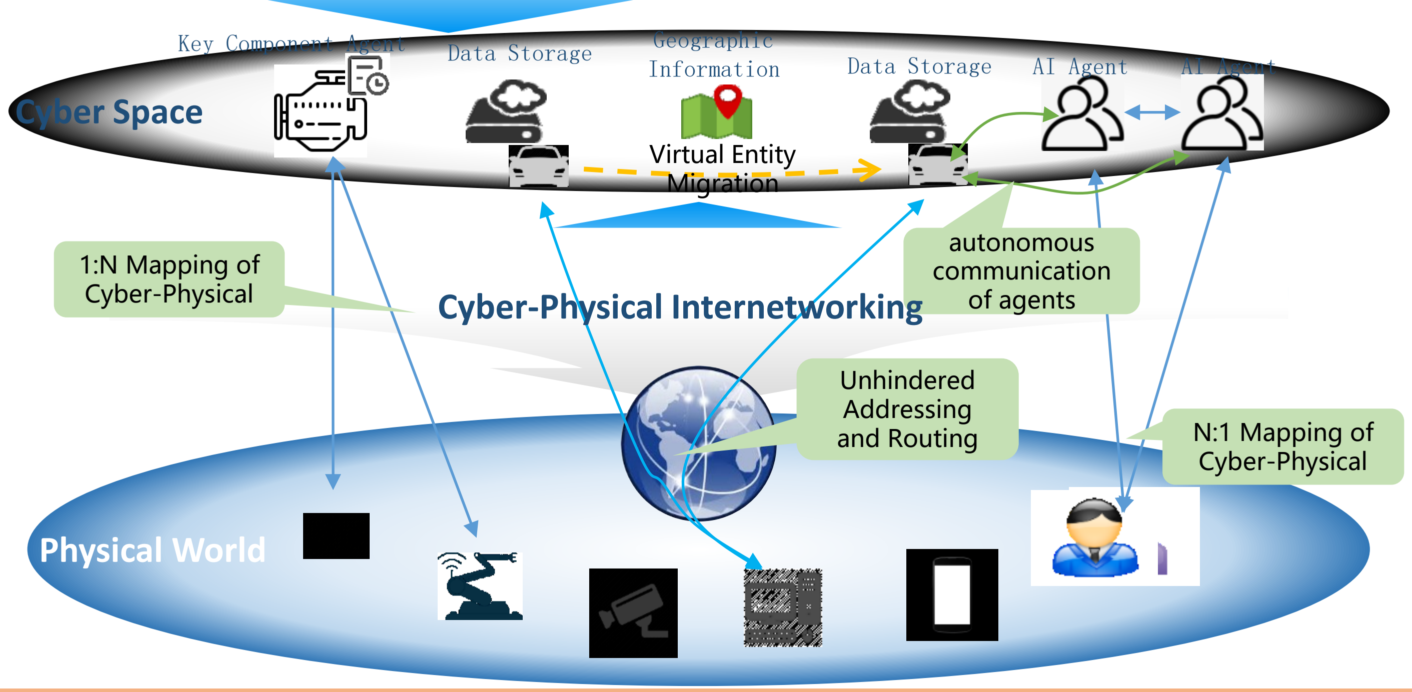
The content in the network acts as an independent communication entity and is no longer bound to specific locations or specific hosts.

The network needs to provide specific QoS and security policies based on user identity, rather than mapping to something instead.

Fusion of Physics and Virtual World

The concept of digital twinning originated in the industrial field and refers to the digital duplicates of physical assets or products, and the connections between them. With the deepening of understanding and the rich research, digital twins have far-reaching influence in the fields of aerospace, intelligent wind power, transportation, offshore oil and gas platforms, industrial manufacturing, health care, and smart cities. Combined with AI, it even creates a virtual space parallel to the physical world [1].

O&M in Aviation | Intelligent Wind Power | Transportation | Oil & Gas platforms | Industrial Manufacturing | Health Care | Smart Cities



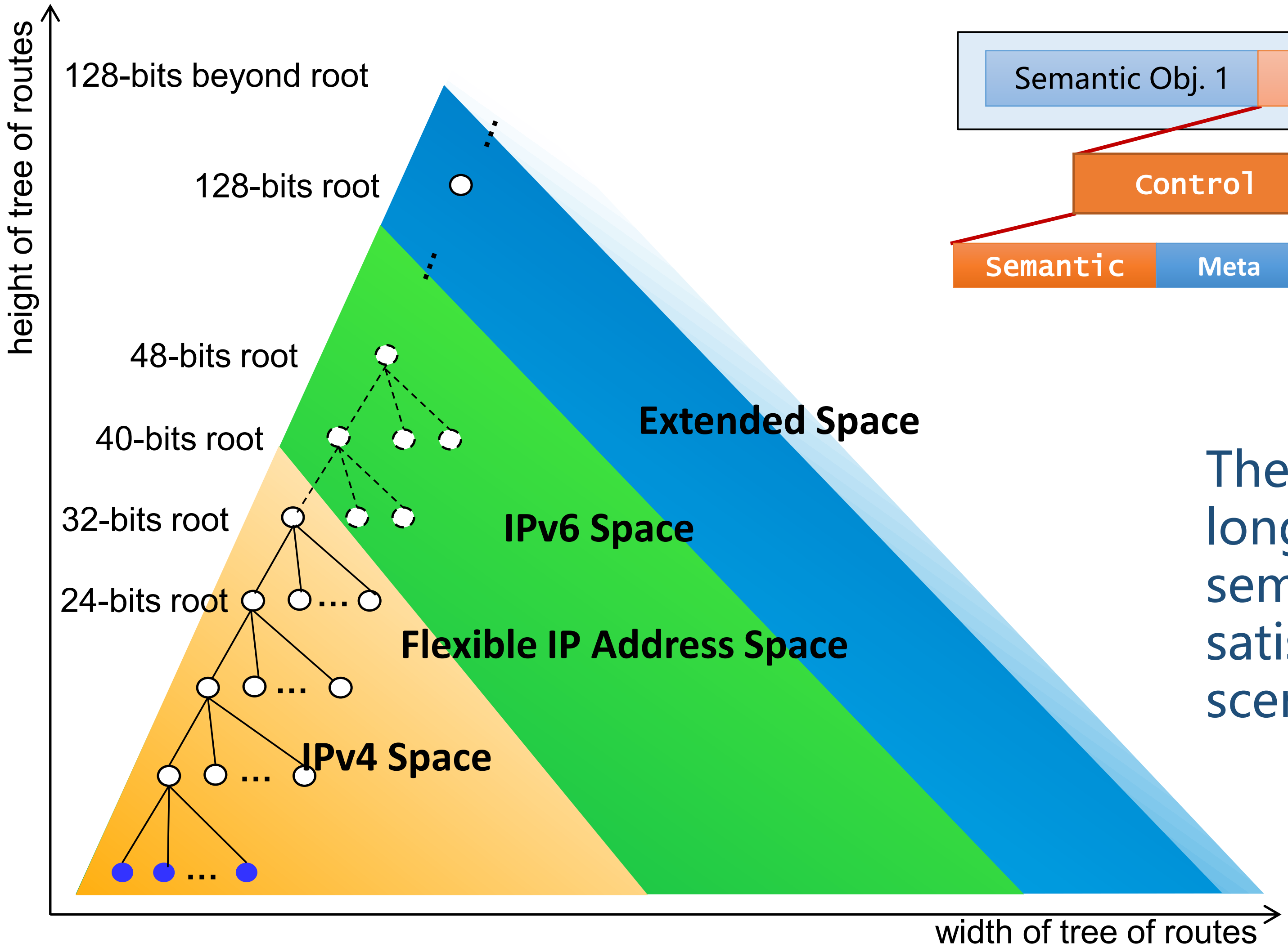
Key network technology requirements

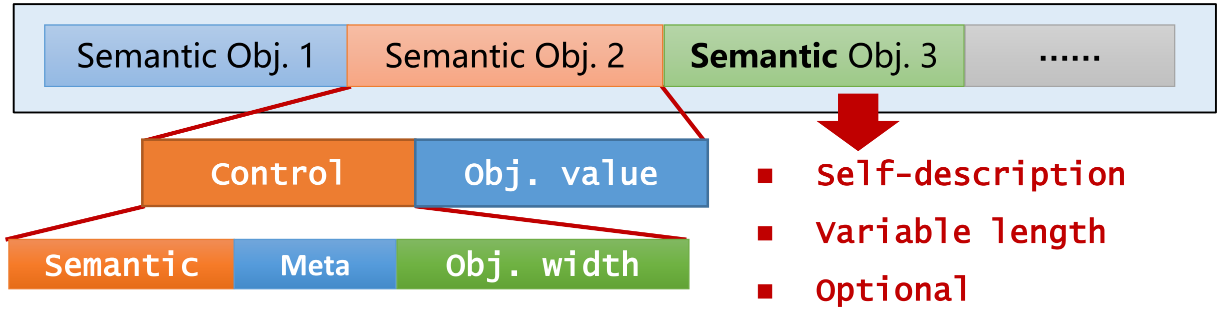
- **Need more flexible variable-length IP addresses to adapt to diverse scenarios and backwards compatible with IPv4, IPv6**
- Supports addressing and routing optimized based on communication entity semantics and digital twin relationships
- Support real-time large-flux communication in virtual-physical fusion scenarios combining ubiquitous AI theory
- Support secure, reliable and resilient connection among massive heterogeneous networks
- Future network architectures supporting multi-ID space and digital twin relationships

The AI-based digital agent will revolutionize the digital structure and stimulate multi-level network interconnection needs: New network characters such as virtual-physical combination and real-time interaction, huge transmission pressure

[1] ZHANG Ping, NIU Kai, TIAN Hui, etc.． Technology prospect of 6G mobile communications． Journal on Communications, Vol.40 No.1． 2019.01

Flexible Address Space

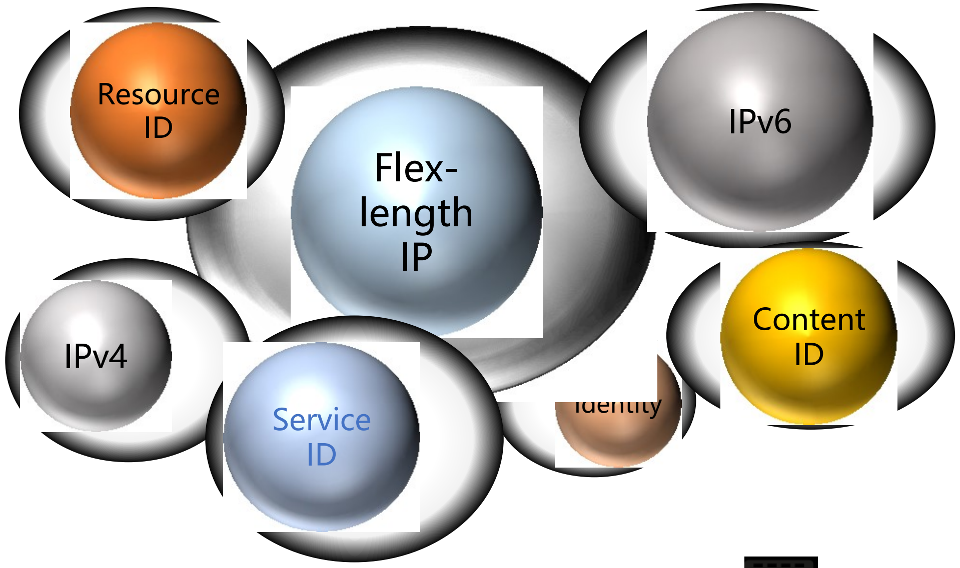




- Self-description
- Variable length
- Optional

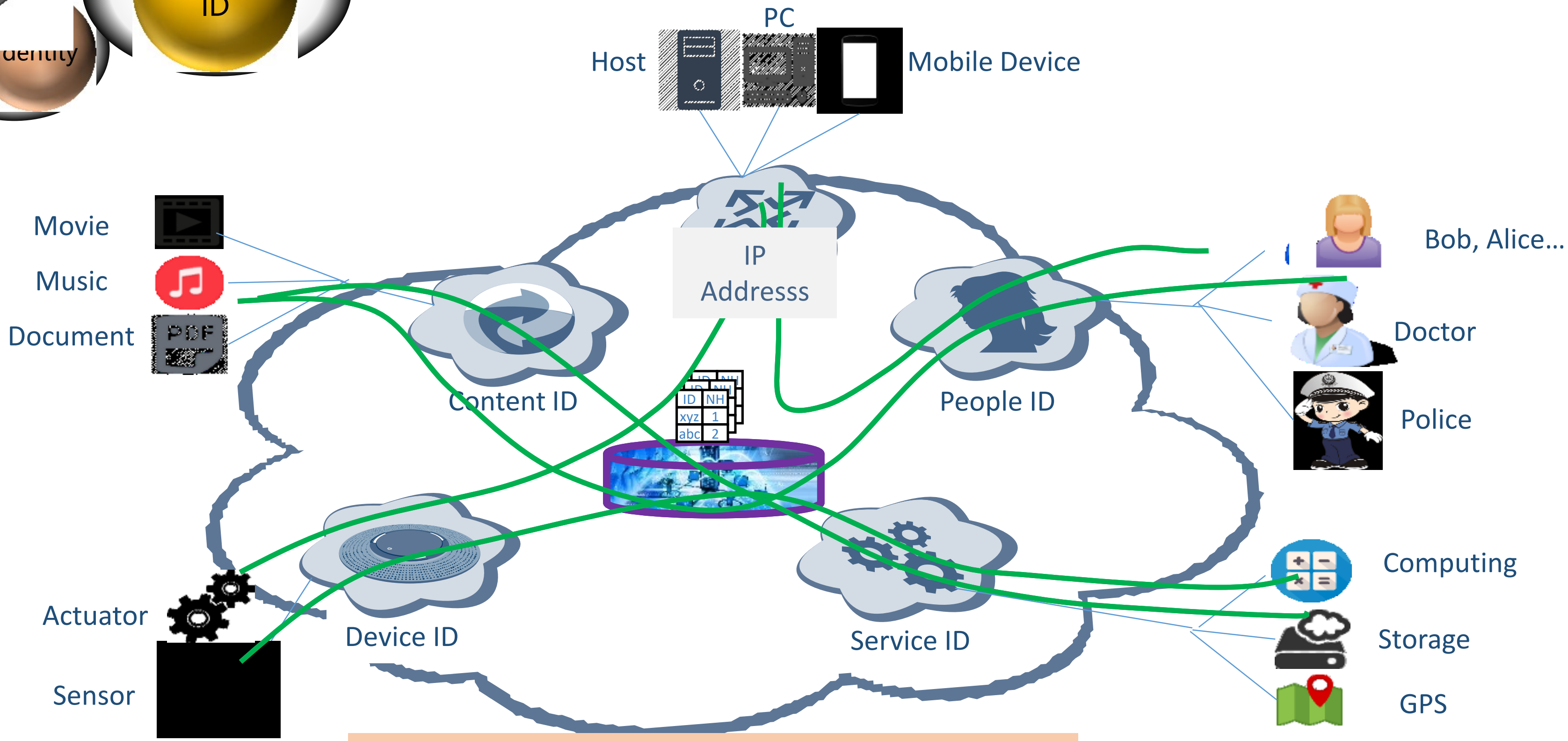
The length of address can be longer or shorter. Furthermore, the semantic fields can be changed to satisfy a variety of communication scenarios.

Multi-Semantic Addressing for Interconnecting ManyNets



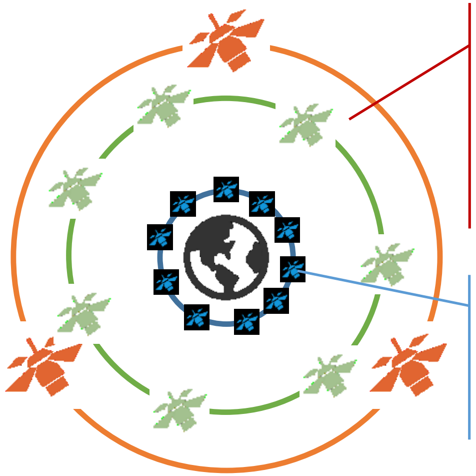
Heterogeneous address space should be able to communicate with each other

Instead of mapping all information into network address, the diverse IDs are used to indicate the destination, which improve routing capabilities.



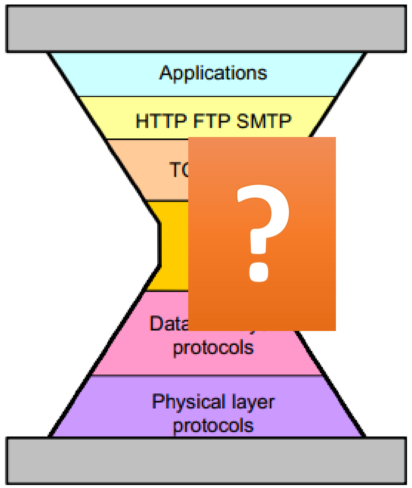
Diversity Addressing and Forwarding

Space-Terrestrial Network



GEO and MEO are hard to provide low latency due to the physical restriction.

LEO can provide end-to-end low latency.



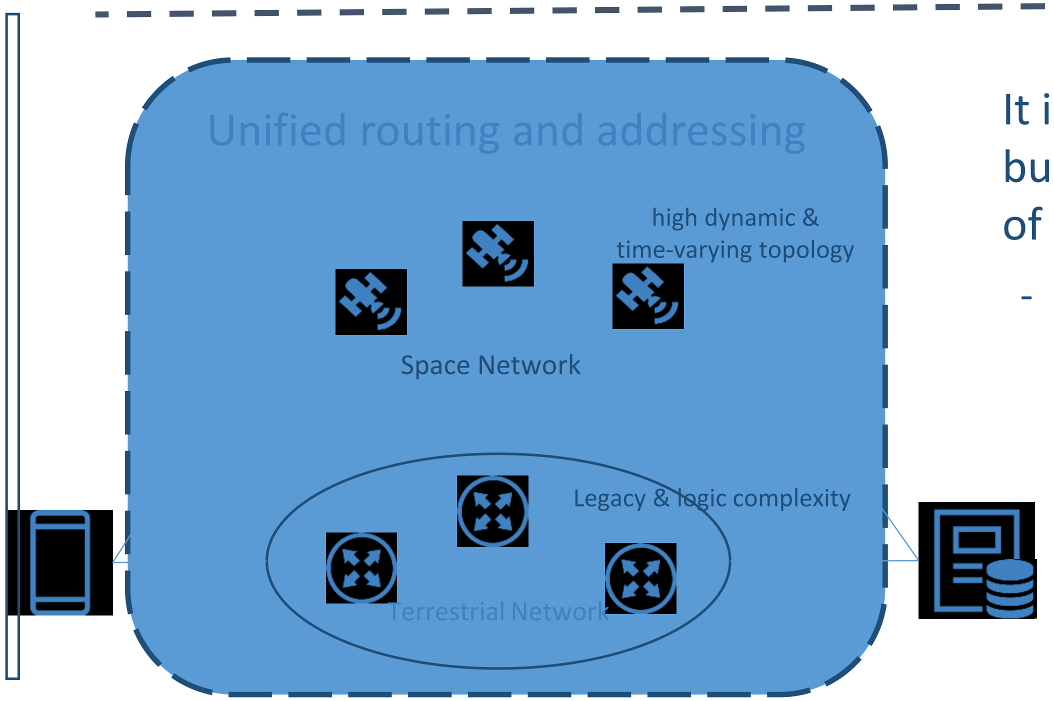
The high dynamicity challenges the traditional IP protocol especially in networking and routing.

- Space network has the characteristics of **high dynamic and time-varying topology**
- The space network channel is **unstable**, the bit error rate could be high

Comparing with traditional optical fiber, space network can provide shorter end-to-end delay in theoretical when the physical distance is more than 3000km*. Space network potentially play one of the most important roles in the future data communication.

Aero/Sailing Broadband

*Mark Handley. 2018. Delay is Not an Option: Low Latency Routing in Space. In Proceedings of the 17th ACM Workshop on Hot Topics in Networks (HotNets '18). ACM, New York, NY, USA, 85-91. DOI: https://doi.org/10.1145/3286062.3286075

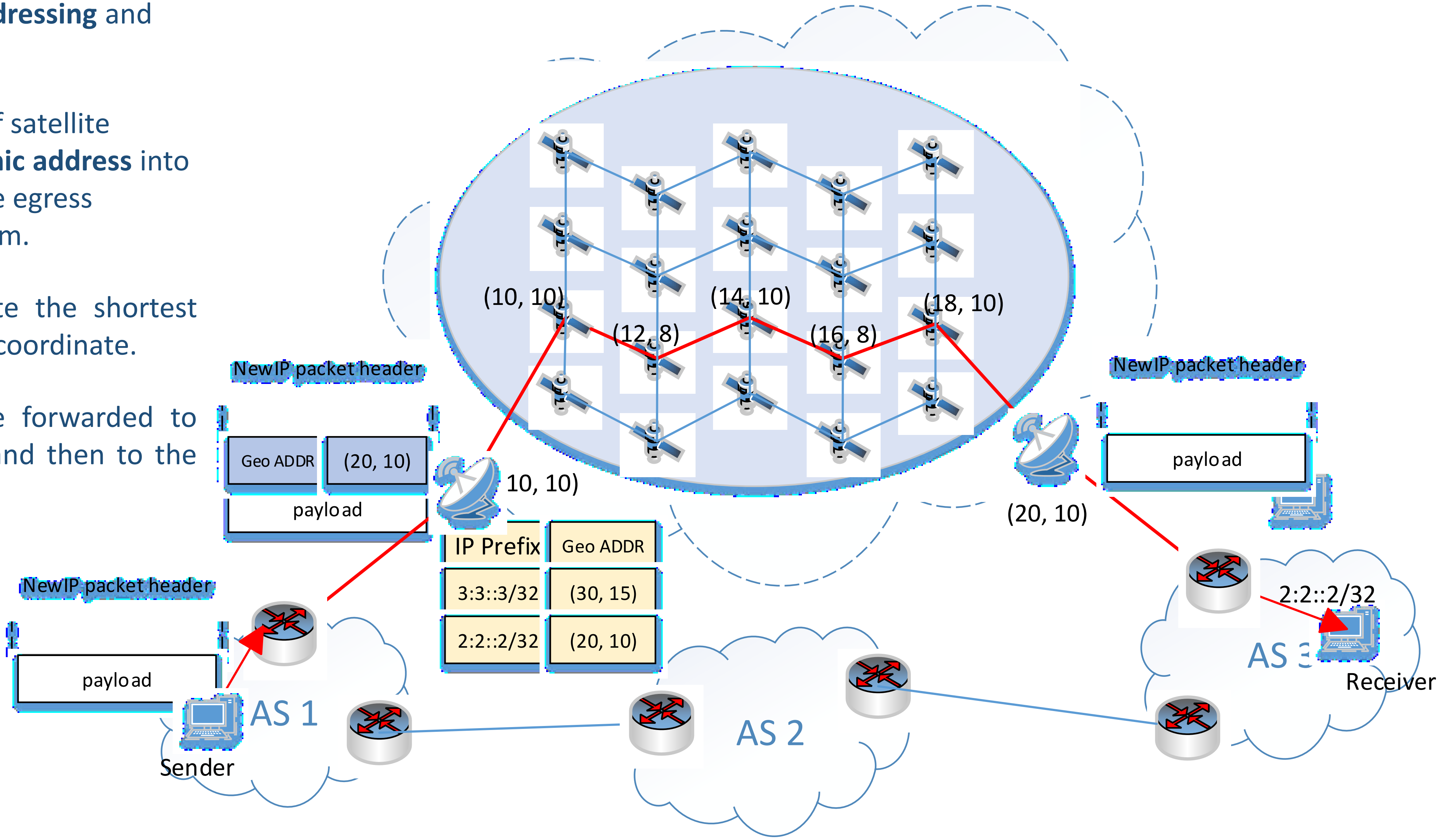


It is a great opportunity to build an integrated network of space and terrestrial

- The architecture of the terrestrial network should be extended, and the new architecture of the space network should be proposed according to its particularity

Support Space-Terrestrial Network and Diversity of Addressing

- Supports **topology addressing** and **geography addressing**
- The ingress gateway of satellite network add **geographic address** into New IP header and the egress gateway delete the item.
- The satellites calculate the shortest path according to the coordinate.
- The data packets are forwarded to the nearest satellite and then to the destination.



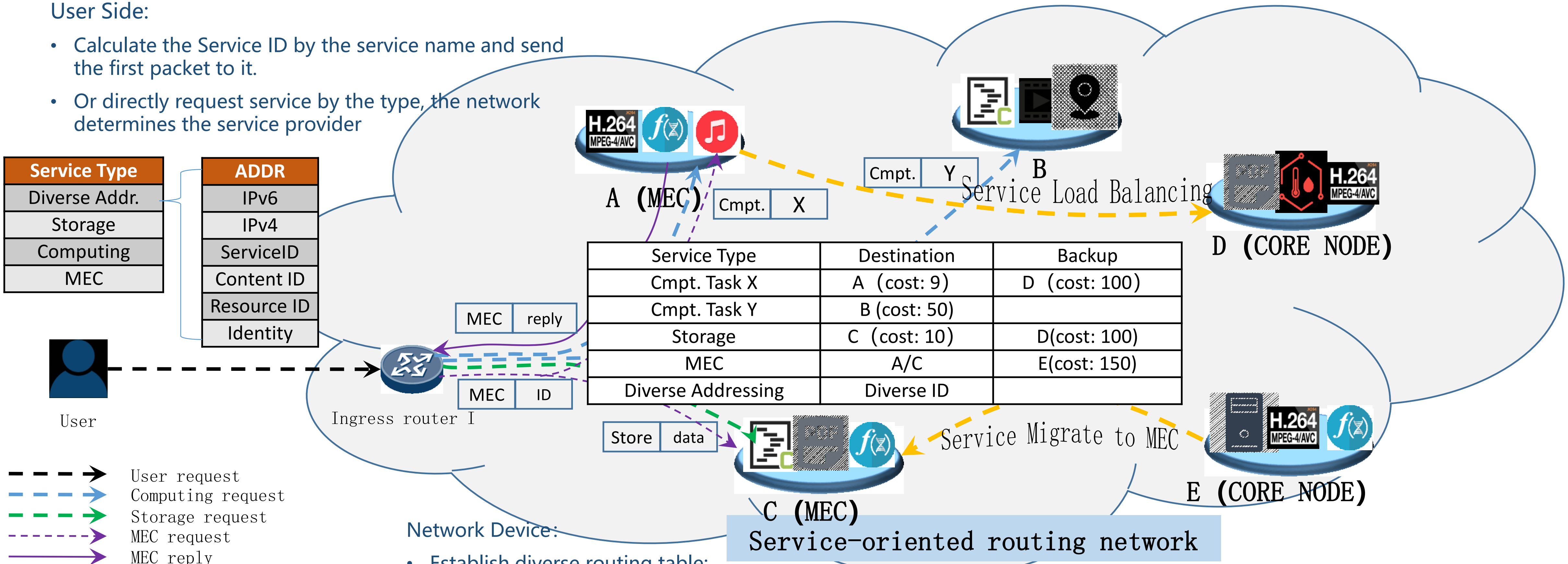
Diverse Addressing - Service-Oriented Routing

Key Ideas:

- **Direct routing based on diverse IDs, maintaining diverse ID routing tables in the network**
- **Some common services even don 't need explicit address or ID. The user provides the service type, and the edge forwards accordingly.**

User Side:

- Calculate the Service ID by the service name and send the first packet to it.
- Or directly request service by the type, the network determines the service provider



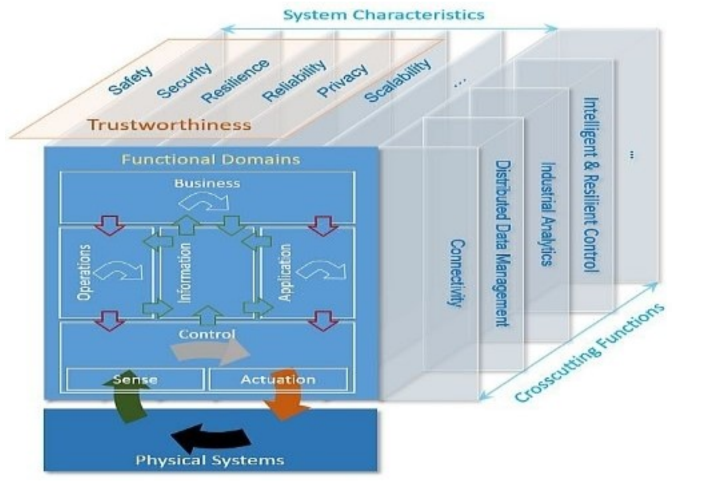
Service Type	Destination	Backup
Cmpt. Task X	A (cost: 9)	D (cost: 100)
Cmpt. Task Y	B (cost: 50)	
Storage	C (cost: 10)	D(cost: 100)
MEC	A/C	E(cost: 150)
Diverse Addressing	Diverse ID	

Network Device:

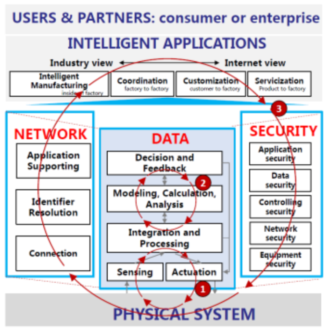
- Establish diverse routing table;
- forward the packet to the destination or the in-network resource node

Verticals: Deterministic Latency, Cooperative Synchronization, Flexible Extension, Diverse Use

IIoT



Connectivity Framework for the Industrial Internet



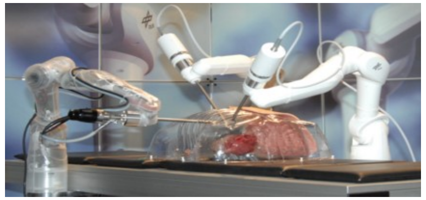
AII: IIoT White Paper 2018

Key Network Metrics for Industrial Internet:

- Extremely low latency: *ms* level (with *us* level jittering)
- Ultra-high reliability: *>99.999%*
- Precise synchronization
- Super-massive connections
- Energy efficiency
- Ultra-high bandwidth for particular applications

Industrial fieldbus is merged with outside network to form Industry Internet, which needs large-scale synchronization with deterministic data transmission.

Tele-Medical Operations

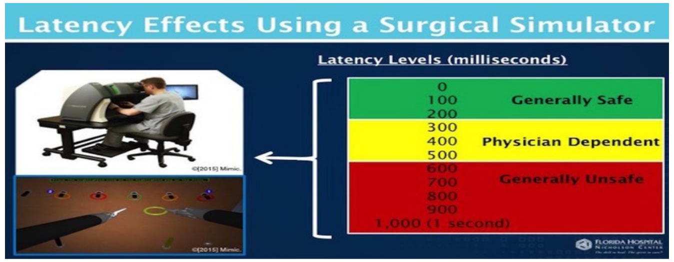


Direct tele-medical service (2001~2020)

MiroSurge system developed at DLR with table-mounted manipulators.

Synchronization via human + machine (~2025)

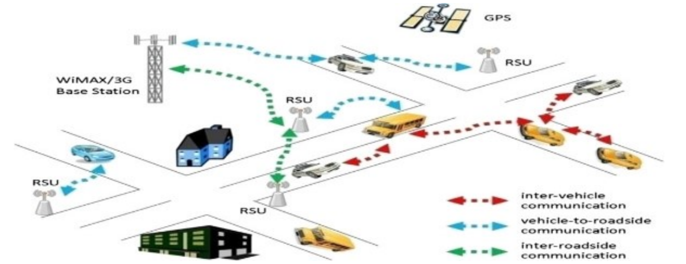
Two surgeons in remote synchronization via **Raven II**



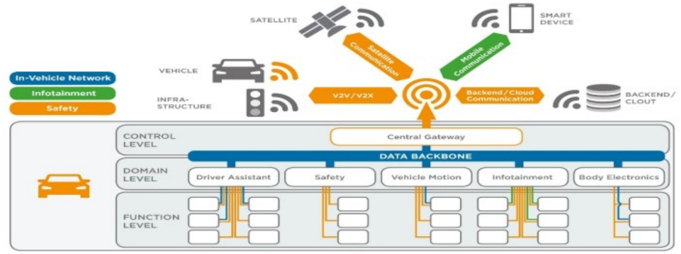
Source: Hospital tests lag time for robotic surgery 1,200 miles away from doctor, 2015

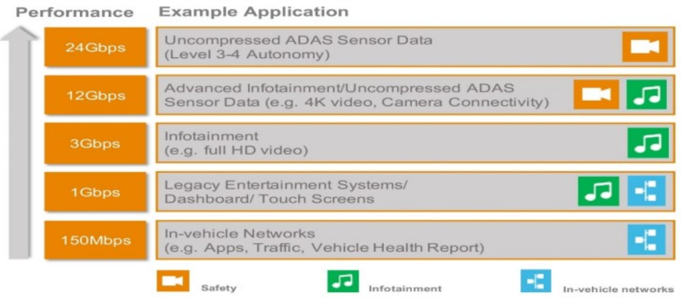
Tele-medical services are emerging with requirements of high-precision coordination, and low latency signaling.

Vehicular Networks



Source: Vehicular Networks





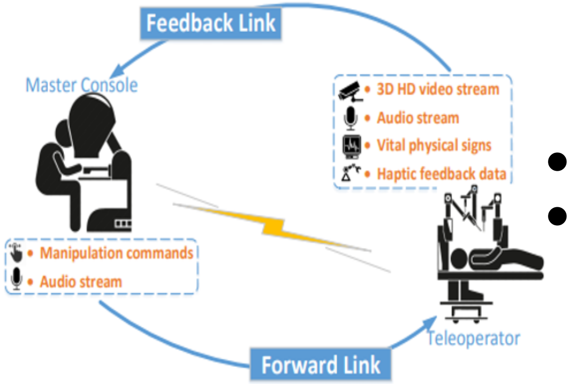
Autonomous Intersection Management

Vehicle-to-X networks enables new communications (X=human/vehicle/road-side/cloud/etc); and in-vehicle data is expected to be boosted dramatically; safety requires ultra-low latency and wide-scale synchronization.

[1] https://www.atlantajewelryshow.com/road-ahead-2019/
[2] http://pro-bind.com/verticalmarkets.php
[3] https://www.sirris.be/blog/first-connectivity-framework-industrial-internet

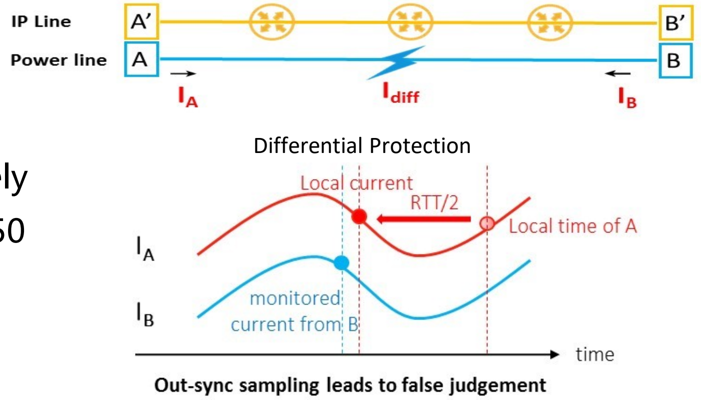
Deterministic Forwarding Provides End-to-End Deterministic Latency Service

New applications require both “in-time” and “on-time”



- A doctor operate a console remotely
- For precise operation, E2E delay< 50 ms, jitter<200us

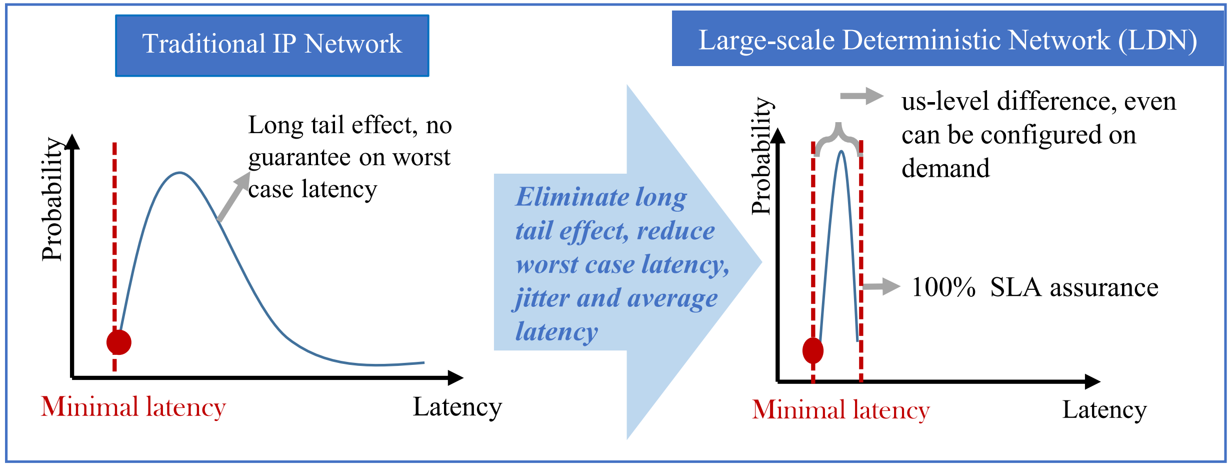
Remote Surgery: requires both “in-time” and “on-time” for the quality of surgery

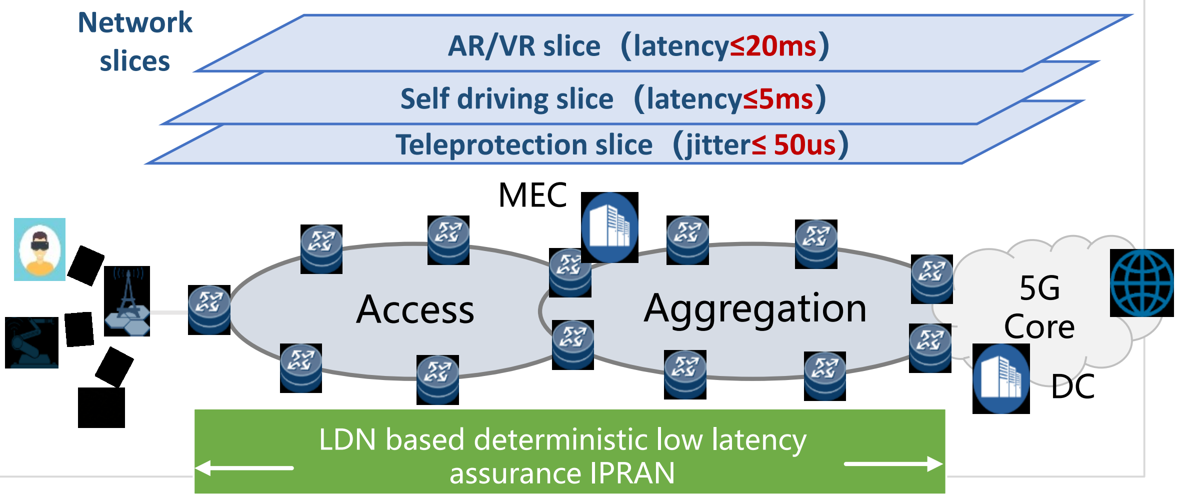


IP-based smart grid: need to transmit electronic control message “in-time”

- Pairing protective devices send the same amount of current to each other.
- In order to avoid error, the difference between two one-way latencies < 200us, jitter < 50us

Enable network layer deterministic forwarding to satisfy future scenarios





End-to-End Communication Requirements for Intrinsic Security

Alice

S

header *payload*

Bob

D

Authenticity

Source IP spoofing

Accountability vs. Privacy

Tradeoff: Exposing IP, port & TTL on wire decreases privacy, but anonymizing them decreases accountability.

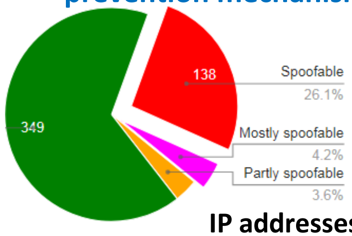
Confidentiality & Integrity

IPSec & TLS can protect confidentiality and intergrity of data communication, and still have to guarantee the security of key exchange from the root.

Availability

Avoid the unavailability of target network resources, computing resources, storage resources, etc. caused by DDoS attacks.

More than 1/3 of the autonomous domains do not have prevention mechanism for IP address spoofing.



IP address spoofing is difficult for a 3rd party to verify.

IP addresses should be real and verifiable

The current key exchange mechanism has many vulnerabilities.

Centralized nodes themselves have lots of security, reliability and configuration problems.

Intrinsic Identity keys & not relaying on 3rd parties

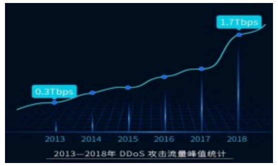
Accountability and privacy for IP packet header fields

IP headers design should take into account a tradeoff between accountability and privacy

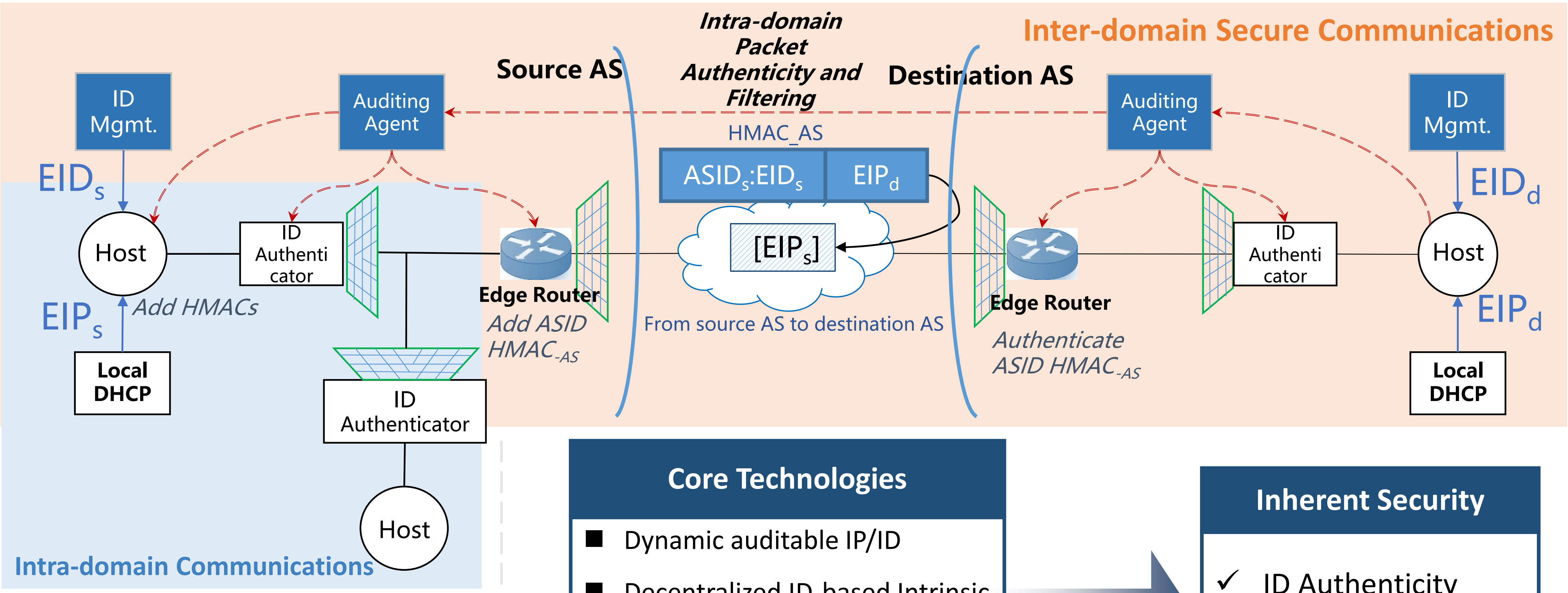
DDoS is a typical problem for network security

It is necessary to combine the authenticity and accountability to build a multi-level verification filtering system for the inter-domain and the intra-domain.

DDoS traffic breaking records very year



Intrinsic Security for Privacy Protection in Future Networks



Shutoff Protocol

EID Encrypted Identifier

EIP Encrypted IP address

HMACs Hash-based Message Authentication Codes

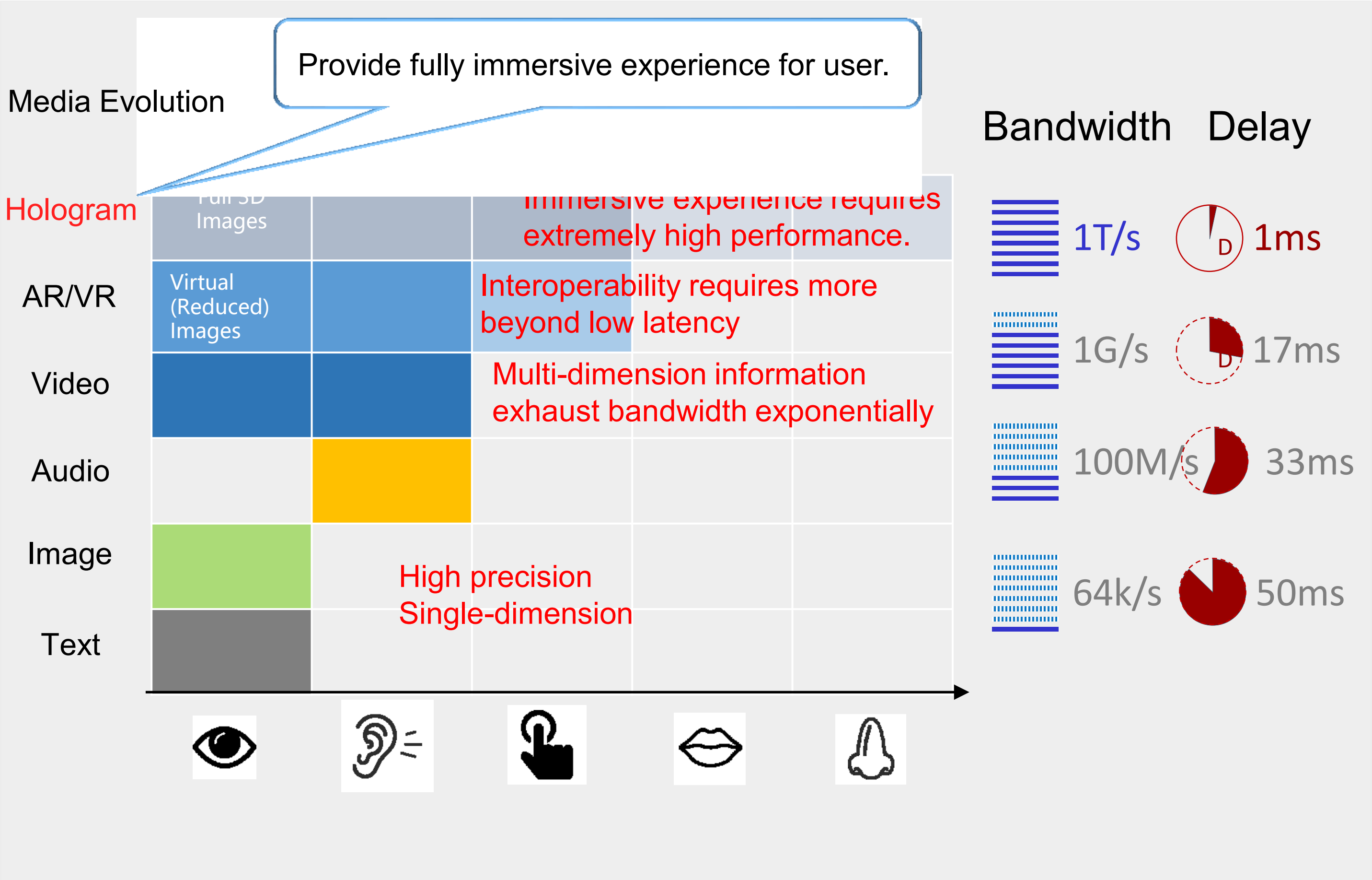
Core Technologies

- Dynamic auditable IP/ID
- Decentralized ID-based Intrinsic Key
- Authenticity for Zero Trust Test
- Joint Inter-AS Auditing and Attack Prevention

Inherent Security

- ✓ ID Authenticity
- ✓ Guaranteed Privacy
- ✓ Immune to DDoS

Evolution of Media

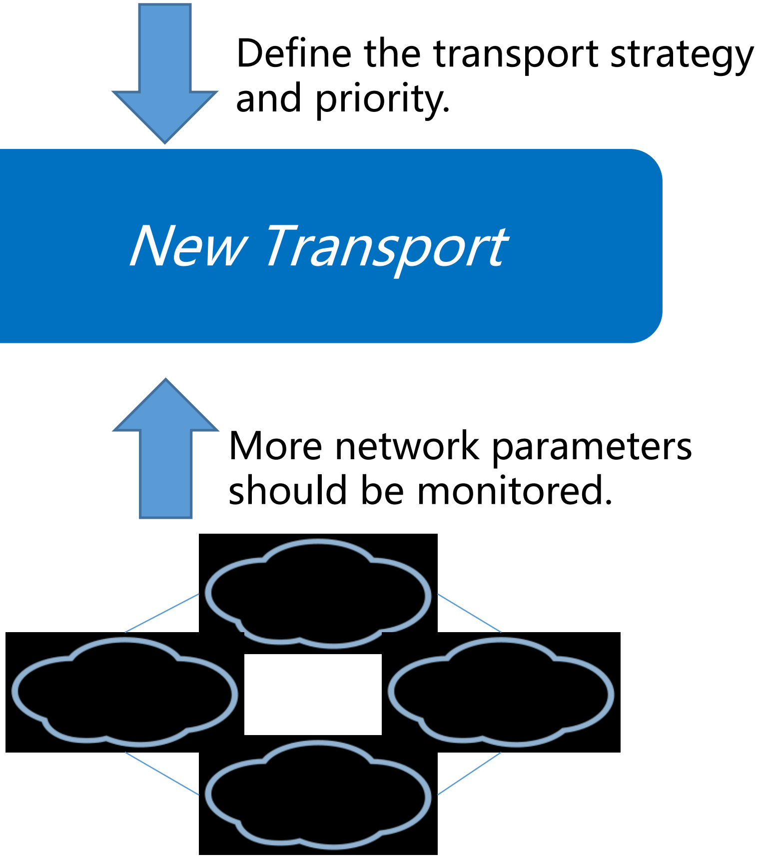


Multi-capturing scheme requires ultra-high bandwidth (as shown in the table). Furthermore, the interaction requires deterministic delay and ultra-high precision synchronization. The loss tolerant feature provides new opportunities for transport layer technologies.

Parameters	Hologram (5.9 inch)	Hologram (70 inch)
Resolution	124,800*70,200	1,536,000*864,000
Dot Pitch	1um	1um
Display Size	12.48 cm*7.02 cm	153.6 cm*86.4 cm
Bits per Pixel	24 bits/pixel	24 bits/pixel
Static Compression	40:1	40:1
Motion Compression	1000:1	1000:1
Static Image Size	5.25 Gbits	796 Gbits
Motion Image Size (at 60FPS)	12.6 Gbps	1.9 Tbps

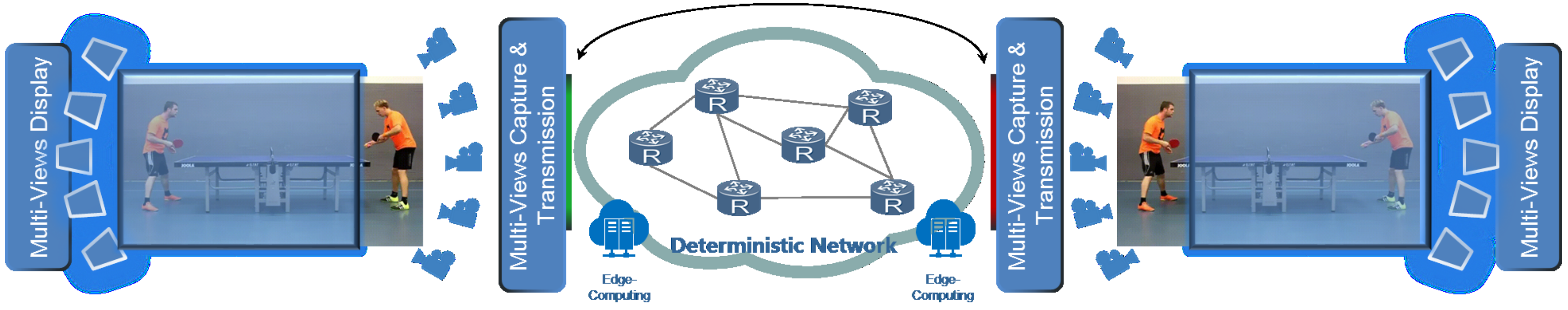
The New Requirements of Holographic Communication

- **Ultra-high Throughput**
  - Along with the evolution of media technologies, the future applications, especially the holographic communication, potentially require ultra-high throughput to the network
- **Customizable Priority and Strategy**
  - The priority and requirement of application data is different. Besides choosing the transport layer protocol, application should own the capability to indicate transport strategy.
- **Reduced Complexity and Indeterminacy**
  - Lossy transmission affects the quality of content however re-transmission (lossless) potentially decrease the throughput. The new transport should consider combining with new technologies, such as network coding, to deal with the packet loss and provide better end-to-end capability.
- **Inherent Network-awareness**
  - Besides packet loss, more parameters, such as bandwidth, queue, delay and jitter, will influence the transport strategy. New transport should be network-aware.

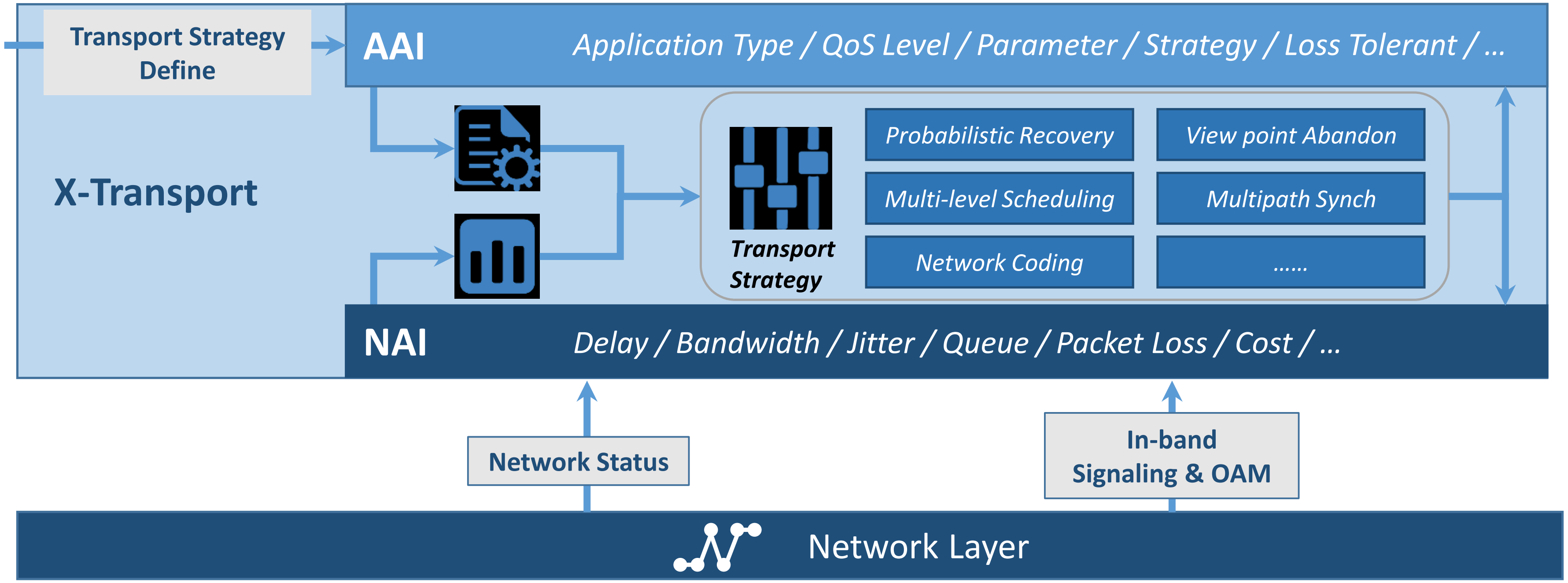


New Transport Architecture

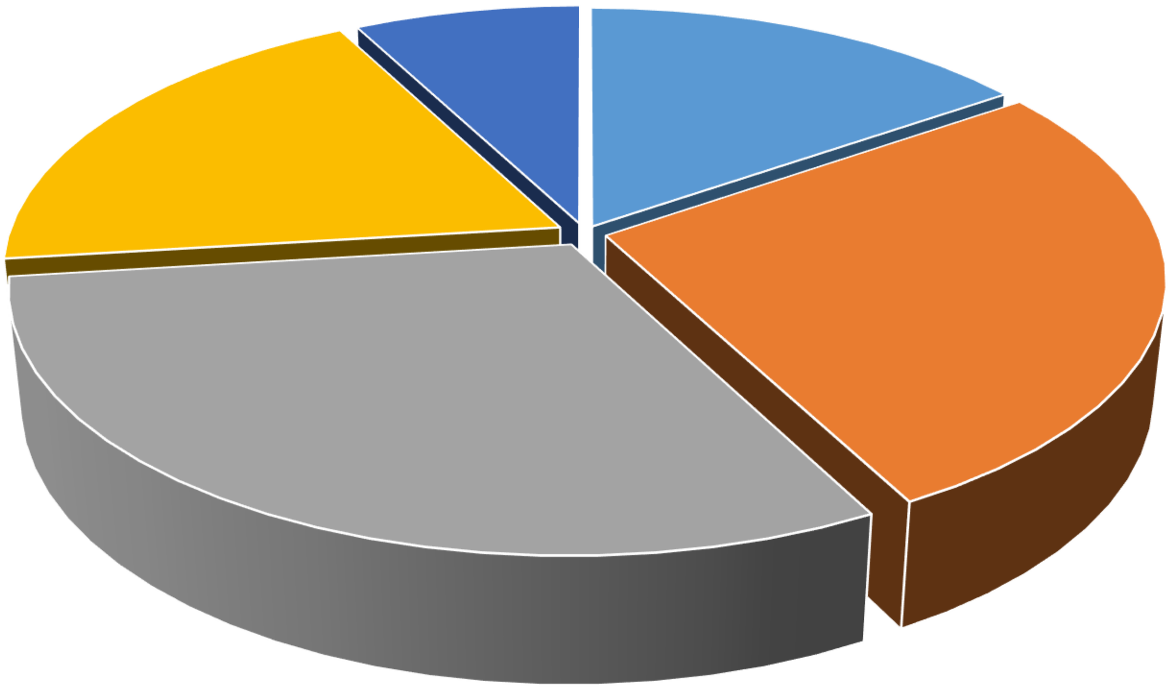
- **Ultra-high throughput:** combining with network coding technology, the new transport layer can satisfy complex network environment. Based on feedback scheme, the dynamic coding rate may avoid re-transmission and then reduce Flow Completed Time so that to improve the transmission efficiency.
- **Ultra-high bandwidth:** by the cooperation of in-band signaling, out of band signaling and network device, the Network Aware Interface (NAI) may plan concurrent multipath which monitors paths' parameters and avoid single path bottleneck. Therefore, optimize the multipath strategy and scheduling.
- **Transport customized**: according to the description from applications, the Application Aware Interface (AAI) may plan the matched transport strategy by considering the data priority, QoS, loss tolerant.



Holographic communication and multipath

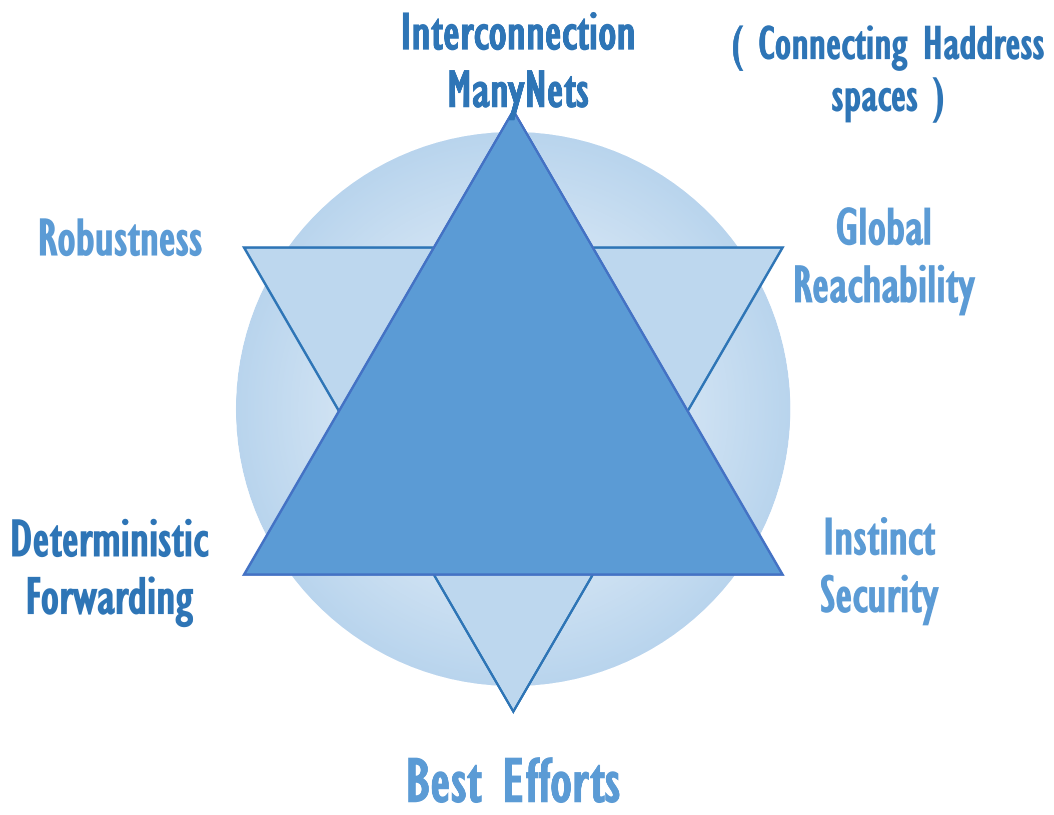


New IP's business value （prediction toward 2030）



New IP will promote trillions-level of investment and business value of new industries

New IP: Provide New Connecting and Capability for the Network 2030



+ Ultra-high Throughput

- **New Connecting:**

  support ManyNets which can connect heteroid address space and variable length IP address directly. Support new kinds of devices, services, capabilities and objects for the future diversity of network

- **New Service：**

  a) provide deterministic service for the upper layer applications, especially for which requires determinacy and is hard to support before

  b) the new transport cooperates dynamically with network layer and provide ultra-high throughput capability.

- **New Capability：**

  a) provide instinct security

  b) provide user definable capability

Thanks!