New IP Networking for Network 2030

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The Merging Trend between Telecommunication and TCP/IP

Time for us to paint the FUTURE NETWORK

Future Network Scenarios & Requirements of Network 2030

Internet for connecting ManyNets

- Converged Space & Terrestrial Network
- Heterogeneous Access Nets & Tech
- New Vertical Applications
- Decentralized Trustable Infrastructure
- Lossless Transmission
- Ultra-realistic Immersive Environment
- Holagram-based Communications
- Holo-sense Teleportation
- Ultra-high (E2E) Throughput

Layer-3 Deterministic Service

- Remote Coordinated Control
- Humanized Avatar
- Industrial Avatar
- High-Precision Transmission (in-time + on-time)
- Real-time Network Recovery (in Emergency or Disaster)
New IP

New IP is IP+, universal IP, flexible IP

Integration of physical and virtual world

Heterogeneous networks and addresses

New addressing and routing scheme

Flex valuable length address

Middle length Address

Long Address

Short Length Address

15min Home

Dinner Ready

22°C

ON

ON

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

Retain the core advantages of IP

New IP

Interconnecting ManyNets (Connect Heterogeneous Networks)

Global Reachability

Intrinsic Security

Best Efforts

Best Efforts

Ultra-high Throughput

Traditional IP

Robustness

Global Reachability

Deterministic Forwarding

Robustness

Best Efforts

Retain the core advantages of IP
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

New Waist

New IP

Satellite Network

Sensor Network

Resource and Services

+ Ultra-high throughput

+ Deterministic forwarding

Best Efforts

+ user customized

+ instinct security

Fixed length IP address

+ multi-semantic addressing

+ variable length address
Interconnecting ManyNets in The Future

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

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

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 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].

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

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

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

Heterogeneous address space should be able to communicate with each other

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.

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**

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

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

Unified routing and addressing

high dynamic & time-varying topology

Legacy & logic complexity
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.

**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

- **System Characteristics**
  - Functional Domains
  - Control
  - Application
  - Connectivity

**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

**Tele-Medical Operations**

- **Direct tele-medical service (2001–2020)**
  - MiroSurge system developed at DLR with table-mounted manipulators.

- **Synchonization via human + machine (~2025)**
  - Two surgeons in remote synchronization via Raven II

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

**Vehicular Networks**

- **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.**

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Deterministic Forwarding Provides End-to-End Deterministic Latency Service

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

- A doctor operates 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

Enable network layer deterministic forwarding to satisfy future scenarios

- 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

IP-based smart grid: need to transmit electronic control message “in-time”
End-to-End Communication Requirements for Intrinsic Security

**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 integrity 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

**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.

**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

DDoS traffic breaking records very year
Inter-domain Secure Communications

Intra-domain Communications

**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

**EID** Encrypted Identifier
**EIP** Encrypted IP address
**HMACs** Hash-based Message Authentication Codes

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**Shutoff Protocol**

Host

ID Mgmt.

Auditing Agent

Source AS

**Intra-domain Packet Authenticity and Filtering**

HMAC_AS

[ASID_s:EID_s] [EIP_s]

Destination AS

Auditing Agent

ID Mgmt.

Host

Local DHCP

ID Authenticator

Edge Router

Add ASID HMAC_AS

From source AS to destination AS

Edge Router

Authenticate ASID HMAC_AS

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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.
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.
New IP’s business value (prediction toward 2030)

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

- Traditional deterministic services: 250 billions $
- Holographic communication: 100 billions $
- Interconnecting of ManyNets (Integration of satellite, UAV, sea and terrestrial networks): 200 billions $
- Vertical industries (Smart transportation, industry, medicine): 400 billions $
- Integration of Physical and Virtual world (including Digital Twin): 350 billions $
New IP: Provide New Connecting and Capability for the Network 2030

- **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!