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Intelligent Eco Networking (IEN): an Advanced Future Internet of intelligence for Digital Social Economic Ecosystem

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***Abstract*—Intelligent Eco Networking (IEN) aims to gradually evolve to be an advanced infrastructure for future Internet of intelligence which treats valuable content data as the first-class entity, motivated by data exchange, manipulated by artificial intelligence, based on the approaches of software defined, virtualized and programmable devices, additionally by comprehensively measuring the cost and gain of storage, computing and network resources, it also integrates decentralized consensus trust preservation and tokenized fine-grained allocation mechanism of blockchain to establish a prosperous mutual-contributed and mutual-beneficial value-oriented networking industry ecosystem.**

***Index Terms*—IEN; Network architecture; IoT; Blockchain; Content-centric**

I. Introduction

With the increasing computation and communication in the age of Big Data and IoT [1] , traditional network architecture is unable to adapt to today's network ecosystem. This incompatibility is reflected in all aspects from network physical infrastructure devices to network software applications.

- Traditional network infrastructure devices are bundled with the functionality it provides, which lead to inefficient, costly and inflexible deployment of new network services.
- Address-based packets delivering service provided by TCP/IP is insensitive to content, making it complex and inaccessible to content that users need.
- Traditional network has poor perception of the network environment, which makes it impossible to quickly and intelligently take effective traffic control measures when network environment changes.
- In the era of the Internet of Everything, various IoT devices with different performances are connected to the Internet, which makes the complexity of the network scene far more than the concept of original designers.

The emergence of some technologies has attracted our attention. ICN [2] and NDN [3] enable the network to perceive the content more granular; NFV [4] and SDN [5] provide more flexible network traffic control measures; Cloud computing [6] and edge computing offer users elastic computing and storage resources; Blockchain [7] ensures data security with a decentralized consensus framework. Blockchain over ICN can implement a simplier and more straight-forward decentralized system, and the BlockNDN [8] can improve effective use of weak connectivity [9], reduce broadcasting overhead and increases network efficiency. However, there is still no a network system that can integrate these technologies well.

In addition, data content value has been established based on a value system witch is constituted by multiple networks [10]. Valued data is in symbi-

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otic interaction continuously within or between networks, thus, mdriving the user-demand-oriented data to be data asset with quantifiable value. In addition to the value generated itself, the data is also associated with some specific services, including storage, transmission, computing, security, quality and applications, and these services cover a range of economic phenomena and issues.

This paper proposes a concept of **valuable content data**. Generally, data with certain meaning can be interpreted as information. In order to build a fair and reciprocal network economy, IEN focuses on the value of the information itself for economic settlement, rather than data flow originally. Valuable content data has three main characteristics: 1. **A variety of different expressions** (data from different IoT devices utilize different encoding methods or compression formats); 2. **Approved value system for recognition and maintenance**; 3. **Directly used for transactions**. Value maintenance and circulation of the cross-value system can be guaranteed since valuable content data itself is a transaction object. Exchanges of data and will be the key to innovation in the scaling and more mature stage of digital transformation.

Therefore, we propose IEN, which has two main goals. Firstly, Propose a future network infrastructure based on value content data, data transaction driving, artificial intelligence control and awareness, software definition, virtualization, programmable device technology route. Then, on this basis, establish a prosperous mutual-contributed and mutual beneficial value-oriented networking industry ecosystem by comprehensively measuring the cost and gain of storage, computing and network resource, and integrating decentralized consensus trust preservation and tokenized fine-grained allocation mechanism of blockchain.

II. Infrastructure

Figure 1 shows the basic architecture of IEN, which is mainly composed of Network functions configurable device, Multi-layer controller system, Content-Centric network protocol, Trust management and Cloud/Fog/Haze computing group. For IoT, the IEN architecture combines with content center, blockchain and AI. We will introduce its infrastructures in detail in this section.

A. Network function configurable device

As shown in Figure 1, the network function configurable device can be the IEN-Hub, the IEN-Router, or IEN-Core Router, depending on its performance. The multi-layer control system can realize different network transmission functions by configuring control processing modules(CPM) in the device to achieve different network transmission functions. The traffic collection module(TCM) can periodically collect network environment information (eg. route table, cache queue length) and traffic information (eg, packet size and receiving frequency). These information will be uploaded to the control panel to assist in formulating transmission strategy. The network function configurable device implements a physical abstraction layer that contains multiple customizable physical interfaces (eg, 5G, wifi, Bluetooth). It makes software applications do not need to consider the underlying heterogeneous environment, and simultaneously access to devices with different performances and different communication methods.

It should be noted that the IEN-Hub is loosely managed by the controller because of its too low computing capability to burden heavy tasks, which only serves as a unified access point for various heterogeneous terminals but can be stimulated for sharing valuable content to earn IEN coins, acting like ”small miners”. And the IEN-Router and IEN-Core Router can not only perform complex network forwarding, but also provide computing and storage for the Cloud/Fog/Haze hierarchical framework, which will be explicated in section E.

B. Multi-layer control system

It intelligently implements transmissions control through configurable device by combining AI Big Data with operator-customized service policies.

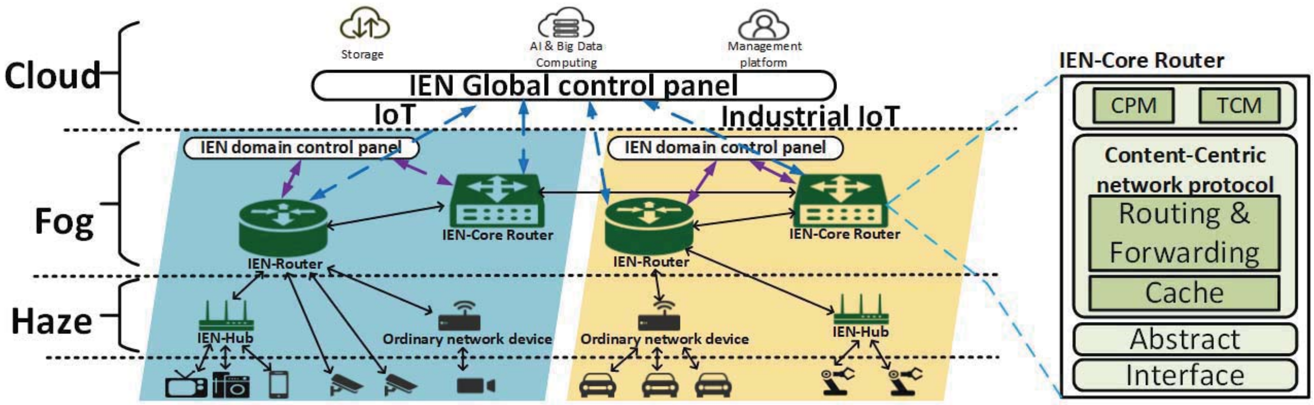

Fig. 1. IEN Architecture and Devices

As shown in Figure 1, we will divide the control system into the IEN domain control panel and the IEN Global comtrol panel. The IEN Global control panel sets regulating the overall network and developing different service forwarding strategies for different services. By learning network flow information with cloud computing, it classifies different data streams into different services and provides corresponding service processing methods. The IEN control panel is responsible for the data forwarding path in the local area network. By learning the network environment information with fog computing, it can plan the forwarding path that is most suitable for the data flow.

C. Content-Centric network protocol

The IEN network protocol uses the content name instead of the address as the data packet header of the network protocol stack. By matching the content name in the data packet, the network can find corresponding data which is needed by users. Each packet content name also carries a mandatory data signature, which ensures the network security. The Content-Centric protocol has a network layer caching function. Transmitted content will be cached in each switch that it traverses, to response that requests for the same content come, switches could search their cache to find the corresponding content and achieve a faster response.

D. Trust management

To ensure the security and stability of the network infrastructure, IEN builds a trust management model to validate data packets. The trust model is based on blockchain technology. The reliability of the trust anchor and the certificates that it issues are guaranteed through distributed consensus. At the same time, the hierarchical structure makes the content name highly expressive and provides a sufficient context for content verification. The trust model supports content-based confidentiality. Content producers can encrypt content after producing it and assign corresponding decryption keys to authorized consumers. In this way, the confidentiality of the content does not depend on the intermediate device to ensure authentic end-to-end confidentiality. end-to-end confidentiality.

E. Cloud/Fog/Haze hierarchical framework

The traditional IoT service framework relies entirely on the computing storage capacity provided by the cloud. With the increase of IoT devices, this framework faces challenges in terms of latency, bandwidth, and device energy consumption. At the same time, more and more network devices still have idle computing and storage resources besides satisfying their own functions.

Therefore, we propose a Cloud/Fog/Haze hierarchical framework for the IoT. The Cloud consists of computer clusters with supercomputing and storage capabilities, providing IoT network with big data analysis and data persistence storage service. The Fog consists of network devices that have better computing and storage performance, such as IEN-Router and IEN-Core Router. The Fog is closer to users and provides a more low-latency and intelligent services. The Haze, which is the closest part of framework to users, consists of network devices with relatively poor performance such as IEN-Hub.

The Cloud/Fog/Haze hierarchical framework is more sensitive to users behavior than the traditional IoT service framework, providing smarter and lower-latency services. Besides, the cloud/fog/haze framework effectively improves the resource utilization of network devices. By employing this kind of framework,, the centralized management and charging model of resources is transformed into a sharing model, forming a new network model and ecology.

III. Echo (focus on incentive)

A. Economic system

The goal of IEN is to build a networked industrial economy with fine-grained token and communist benefits, which is embodied in the "valuable content data ecological market economy" . The game theory model describing economic problems consists of three parts: participants, strategies and payoffs. IEN utilizes utility function to model payoffs of the economic problem based on income implementation. In the context of the Internet of Things, supported by network technology, with valuable content data as the first-class entity, through the integration of cross-border industry chain, the horizontal user relationships expand to break the current industrial boundary and subvert the traditional network. Based on user-demand-orientated value, IEN optimizes the production, transfer and circulation of value, constructing a reasonable "production relation" for the prosperous network "productivity", and realizing the ecosystem of value reconstruction on chains.

The ecosystem constructed by IEN is incarnated as a virtuous circle. For one thing, it is supported by the technology of solving the reliable transfer of credit under the decentralized or weakly centralized scene of the blockchain, and establishes the consensus trust and publicity of different value systems across human society. For another, a reasonable distribution mechanism is created through the fine-grained token quantitative value, so as to promote closer coordination, division of labor and cooperation, and form a multi-level incentive social relationship based on trust. The essence of IEN ecosystem is to achieve a win-win prospects under free mutual benefit communism and fair sharing doctrine.

B. Proof of Valuable Content Sharing

The ensure of Blockchain security is critical. The proof method of POW [11] requires a lot of waste computing to find a solution to the problem. In IEN, if the output by the node is valuable to the user, not just to ensure the security of the blockchain. We determine that the work done by the nodes in the consensus agreement is useful. We design a consensus agreement for useful work based on valuable content sharing.

Imagining such a Marketplace. In this Marketplace, the IoT devices produce valuable content data and is sent as content producers to consumers who need it. As the actual transmission node of these valuable content data, routing devices in the network,such as IEN-Hub, should receive corresponding benefits. Note that the benefits here are only for the transmission of valuable content data. The transmission of other type of data, such as control data, will not yield revenue. Even if the devices transfer harmful data, such as a virus, they should also be punished accordingly. For such an IoT scenario, we propose Proof of Valuable Content Sharing (PVCS), a blockchain consensus algorithm for valuable content. The core idea is that the more computing and storage resources a network device spends on valuable data, the greater the allocation to the accounting rights.

PVCS consensus mechanism of blockchain is characterised by majority rule and fairness rule. Majority rule does not refer to the number of nodes, but takes the computing and storage resource that the node spends for valuable content. Fairness means that nodes have the equal right to give priority to the consensus when matching certain conditions. Consensus ensures verifi-

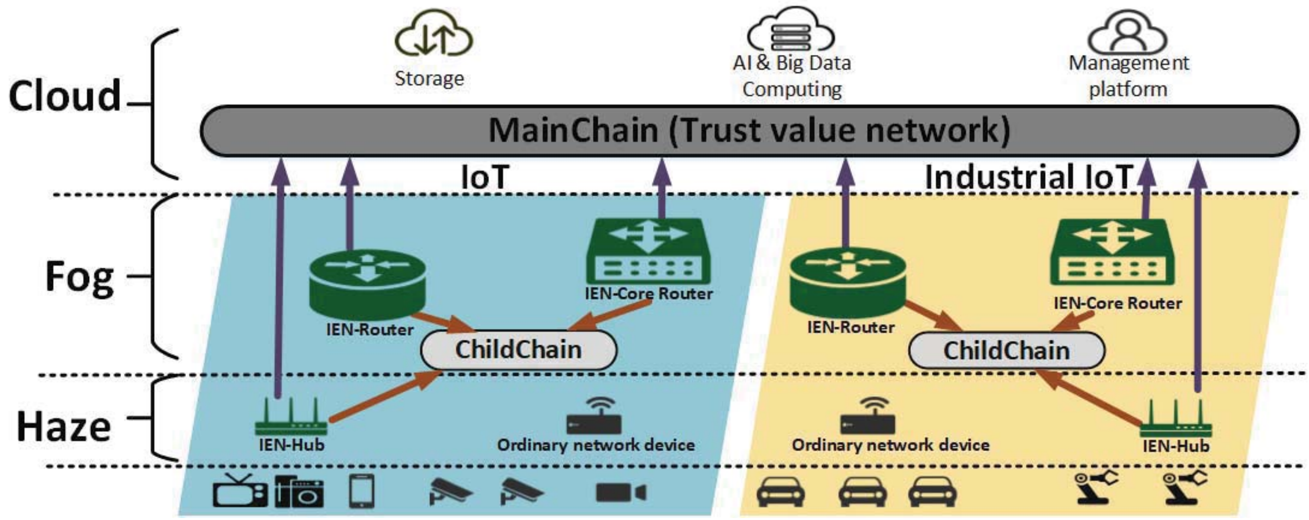

Fig. 2. IEN Blockchain

cation and consistence by the majority of participating nodes across the network finally.

VRF [12] has the greatest advantages of rapid consensus, anti-attack capability and extremely low computing power, which is in line with the needs of IoT. PVCS uses Directed Acyclic Graph (DAG) data structure for IoT to implement distributed and irreversible information transfer. At the same time, the PVCS algorithm should also adapt to the scalability of the Internet of Things consensus network. The PVCS algorithm can be summarized as follows:

Each node generates a block as a leader candidate. Before the next round of consensus is about to begin, PVCS determine if the node is a leader candidate by equation:

$$H\Big(Sig(\triangle t, 1, Cont(V,C,S))\Big) \leq 1/size(W_{\triangle}t) \quad (1)$$

$H\Big(x\Big)$ represents a computable hash function, that maps arbitrarily long strings to fixed-length binary strings. $Sig\big(x\big)$ is a digital signature defined by the time value between two rounds of consensus: $\triangle t$, and valuable content parameter $Cont(V,C,S)$. V demonstrates the value of the content forwarded by the node. C and S represent computing and storage resources for nodes to forward valuable content consumption. $size(W_{\triangle}t)$ is the number of public keys participating in the block consensus in the network in the $\triangle t$, that is the number of wallets. The true leader is the smallest hash among all candidates. According to the

$$H\Big(Sig_i(\triangle t, 1, Cont(V,C,S))\Big) < p^k \quad (2)$$

multiple verifier nodes from the consensus network are selected and the final consensus result is determined. $Sig_i\big(x\big)$ is the Digital signature of i node. p^k represents the random probability generated by the k-th round of consensus.

As shown in Figure 2, aiming at future network of millions which consists of intelligent nodes. The consensus mechanism of IEN relies on constructing a Multi-Blockchain architecture to minimize the barrier of scalability. A ChildChain driven from various user demand functions as a child blockchain within the global MainChain, whose consensus can be customized. No trust exists between ChildChains where consensus and token Exchange are implemented through global MainChain.

- Data demander (the Cloud layer) provides a reliable globally consistent MainChain.
- Data owner (the Fog layer) supplys ChildChains issued by various functions or services.
- Data producer (the Haze layer and IoT terminal) interacts directly with the MainChain or ChildChains with valuable content data.
- Data Broker (IEN devices) helps storing, forwarding and searching valuable content.

C. Tokenized fine-grained allocation mechanism

Future Internet of Things is approaching value implementation of all resources. The primary prerequisite for industry economy of value network is the evaluation of reliable data content values and effective incentives to plan the issuance and distribution of tokens. The value of each node follows the state of network for effective fine-grained distribution by migrating valuable content data from application to the protocol layer, thus constructing a fair production relation of network, promoting the development of network ecological civilization.

As the value consensus of nodes, the circulation of token in the ecology represents the formation process of ecological value, which is equivalent to the primary market of token. As in the vehicle networking, road conditions captured by cameras will be accompanied by transactions and settlements in the navigation and real-time radio applications. The incentive system of the intelligent IoT device relies on the whole network data to trace and settle profits. With the circulation and transactions outside the ecosystem, token represents the ecological value through the Internet, forming the secondary market. Specifically, token does not just record transaction, but involves the attributes, providing a reliable basis for the reasonable traceability of secondary transaction settlement based on blockchain.

The allocation mechanism of IEN involving future million intelligent terminals is applied to distributed autonomous scenarios. Given the fact that the participating nodes only know their own utility function without acquaintance of others, the incomplete information game theory is introduced to define rational allocation of the mixed strategy Nash equilibrium solution:

Participating node set $N = \{1, 2, ..., N\}$, σ Indicates a mix of strategy combinations, S is a set of pure strategy s that represents each node, income $a_i(\sigma)$ of node $i \in N$ is a random variable of $\{a_i(s)|s \in S\}$. For all nodes $\tilde{A} = \{a_i(\sigma)|\sigma \in M, i \in N\}$, where M represents a collection of mix strategies, preference order of i in $\tilde{A}$ can be defined as $\succeq$. According to Representation Theory under certain conditions, there is a continuous utility function $u_i(\sigma) \equiv u_i(a_i(\sigma))$, making $a_i(\sigma) \succeq a_i(\sigma)$ equals to $u_i(a_i(\sigma)) \geq u_i(a_i(\sigma))$. When u_i represents the expected utility function:

$$u_i(\sigma) = \sum_{j_1=1}^{k_1} \sum_{j_2=1}^{k_2} ... \sum_{j_n=1}^{k_n} u_i(a_i(s_1^{j_1}, s_2^{j_2}, ..., s_n^{j_n})))p_1^{j_1} p_2^{j_2} ... p_n^{j_n} \tag{3}$$

After utility function $u_i(i \in N)$ is defined , the distribution mechanism is described as utility model:

$$E = (N, (S_i)_{i \in N}, (a_i)_{i \in N}, (u_i)_{i \in N}) \tag{4}$$

strategic combination $\sigma^* = (\sigma_1^*, \sigma_2^*, ..., \sigma_n^*)$ indicates Nash Equilibrium on E for each $i \in N$:

$$u_i(a_i(\sigma_1^*, \sigma_{-i}^*)) \geq u_i(a_i(\sigma_i, \sigma_{-i}^*)), \forall \sigma_i \in M_i \tag{5}$$

The fine-grained token solves the problem of confirmation, and transaction through blockchain realizes the maintenance and circulation of value. The popularity of such technology will accelerate the implementation of the basic ecological agreement of "the survival of the fittest", which promotes the pace of future social civilization prosperity and innovation.

IV. Conclusion

With the increasing computation and communication in the age of Big Data and IoT, traditional networks have shown various drawbacks from the physical hardware to the transmission architecture. At the same time, Valued content data are continuously in symbiotic interaction within or between networks, making the network a huge value market. In this paper, our contribution can be summarized as the following: Firstly, we propose the IEN architecture for IoT, combining with content center, blockchain and AI. Secondly,we propose a mutual-contributed and mutual beneficial value-oriented networking ecosystem by integrating decentralized consensus trust preservation and tokenized fine-grained allocation mechanism. Thirdly,we propose PVCS algorithm based on valuable content to achieve a reliable consensus for IEN. In the future, our work will be focus on the deployment of IEN network architecture and the improvement of ecosystem theory.

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