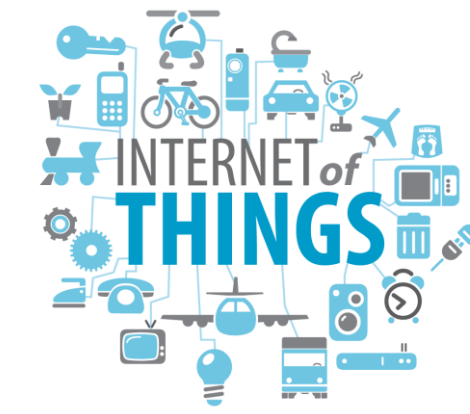


Background

New age of “Internet of Things” (IoT) will network 50 billion devices by 2025.

- ❖ Smartphones, sensors, watches, bulbs, webcams, etc.



Conventional cloud computing falls short because:

- ❖ Massive data volume and high-speed accumulation at edge
- ❖ Some apps require fast response and low latency: AR/VR, self-driving, etc.
- ❖ Resource-poor IoT devices need “closer” resource assistance

Edge (fog) computing brings more resources close to the IoT devices; share resources among IoT applications and IoT devices

- ❖ Enable new “Edge-IoT” Architecture
- ❖ Enable apps in smart home, smart city, smart transportation etc.

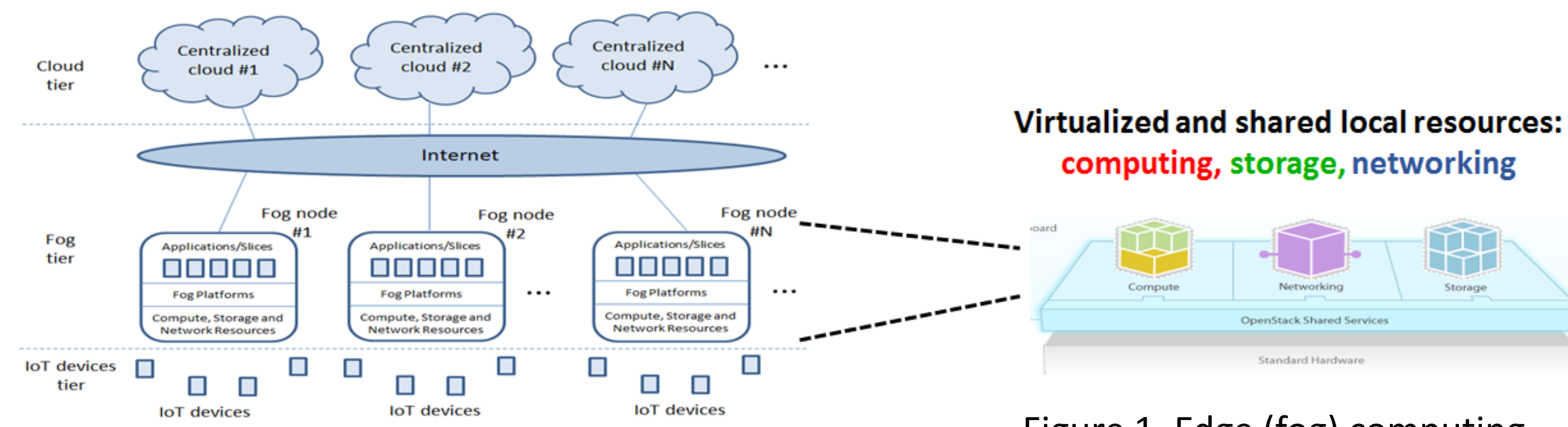


Figure 1. Edge (fog) computing

Research Problems

Major challenges: IoT devices can be both “weak” and “vulnerable”

- ❖ Weak: limited capabilities, needs offloading tasks to edge
- ❖ Vulnerable: easy to be hacked and turned to botnet

The edge server can act as a gateway to (1) enforce security policies and (2) allocate resource dynamically for IoT devices.

Problems:

- How an edge server monitors device activities and detects malicious behavior using a secure and enforced mechanism?
- How an edge server dynamically and optimally allocates limited resources for various IoT devices and apps?

Our Proposal

We propose a new “Credit-Coin” solution utilizing blockchain and smart contracts for secure device management and optimal resource allocation. The edge servers running the new credit-coin system is called “Edge Chain” platform.

Blockchain is deployed on Edge-IoT to record all the activities and transactions (including malicious behavior) into the blockchain automatically.

- ❖ Data persistence
- ❖ Tampering resistance
- ❖ Distributed storage and validation



Smart contracts run on the blockchains to perform the Credit-Coin based resource management without third-party interference.

- ❖ Self-executing
- ❖ Events-triggered
- ❖ Rules-enforced



System Design

System Modules

- IoT Proxy: accommodate legacy IoT devices and offer backward compatibility
 - ❖ Create blockchain accounts and interact with blockchain for legacy IoT devices
 - ❖ Non-legacy devices can interact with blockchain directly
- Smart Contract Interfaces
 - ❖ Bridge between IoT devices and the smart contracts
 - ❖ Web3.js protocol, Javascript based APIs
- Smart contracts
 - ❖ Digital currency system for credit-coin management
 - ❖ Policy management: analyzes devices behavior and enforces resource policies
- Blockchain server
 - ❖ Provides blockchain services; executes smart contracts
 - ❖ Records all activities and transactions on blockchain; mines new blocks
- Application interfaces and Edge Resource Provisioning
 - ❖ Application interfaces trigger resource provisioning; using Node.js framework
 - ❖ Edge servers provision resources for IoT devices and apps

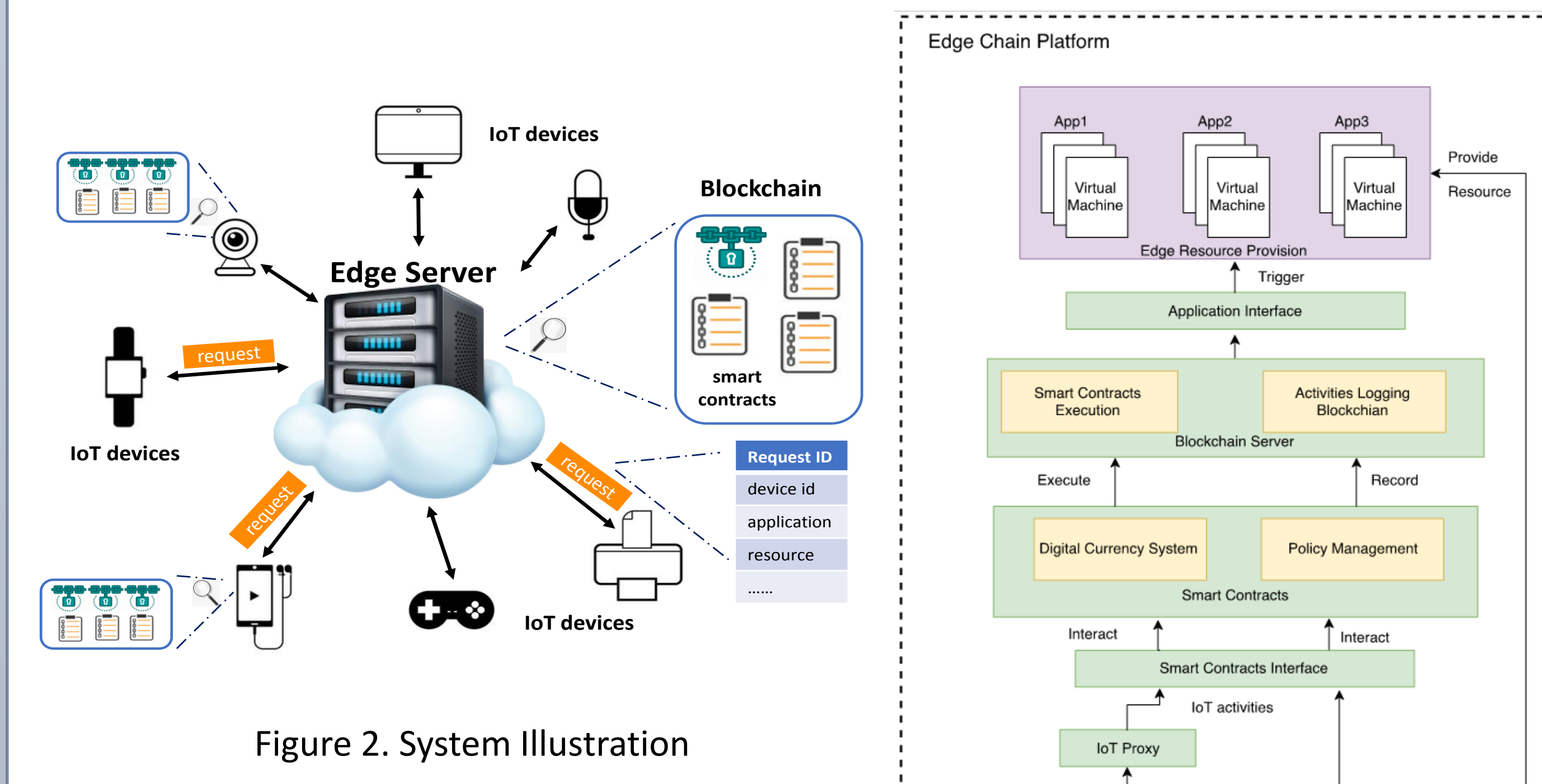


Figure 2. System Illustration

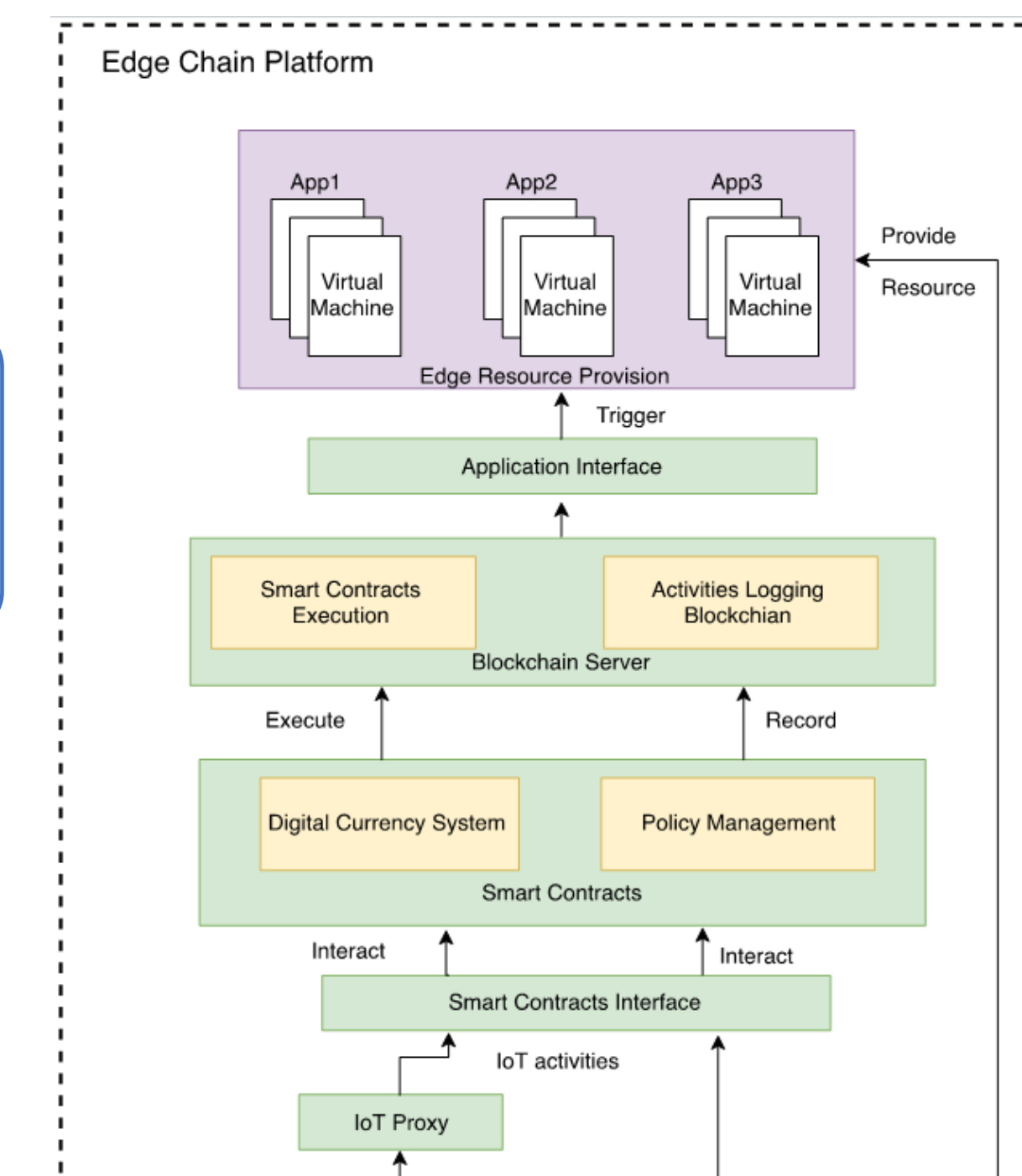


Figure 3. System Modules

System Workflow

Four Key Procedures for the proposed Edge-Chain system.

- ❖ Blockchain implementation
 - Install blockchain on the edge servers and sync across multiple devices
- ❖ Smart contracts deployment
 - Write, test, run, and deploy smart contracts over blockchain
- ❖ IoT devices registration
 - Process different for legacy and non-legacy IoT devices
 - Create accounts and add attributes to smart contracts; initial coins assigned
- ❖ IoT device activities management
 - Legacy: monitor and audit behavior; Non-legacy: could obtain edge resources through smart contracts and blockchain
 - Charge devices accordingly; penalize bad behaviors; all transactions recorded

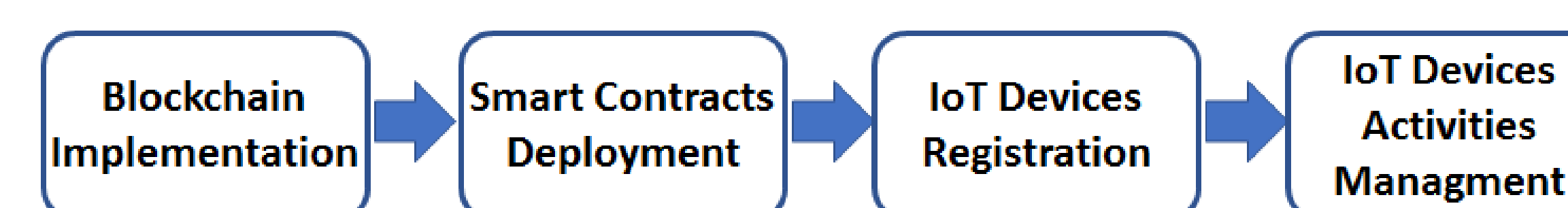


Figure 4. System Workflow

System Prototype and Experimentation

An Edge-IoT testbed is built on UMSL campus, which includes:

Hardware:

- (1) Edge server: one HP ProDesktop (3.2GHz CPU, 16G GB RAM, 1TB storage); a dedicated high-performance edge cloud is under final configuration.
- (2) IoT devices: two laptops, Raspberry Pi (Model B), sensor hat, webcams.

Software:

- (1) Edge server: Ubuntu operating system; OpenStack cloud computing platform
- (2) Blockchain implementation: Geth 1.8.2; Truffle 4.0.6; Solidity 0.4.19; Web3 0.2

Application Test: Smart home front door video monitoring

- ❖ Video frame processing: Face detection
- ❖ Edge resources type: bandwidth, computing
- ❖ Overhead: 1.2s for the interaction with smart contract

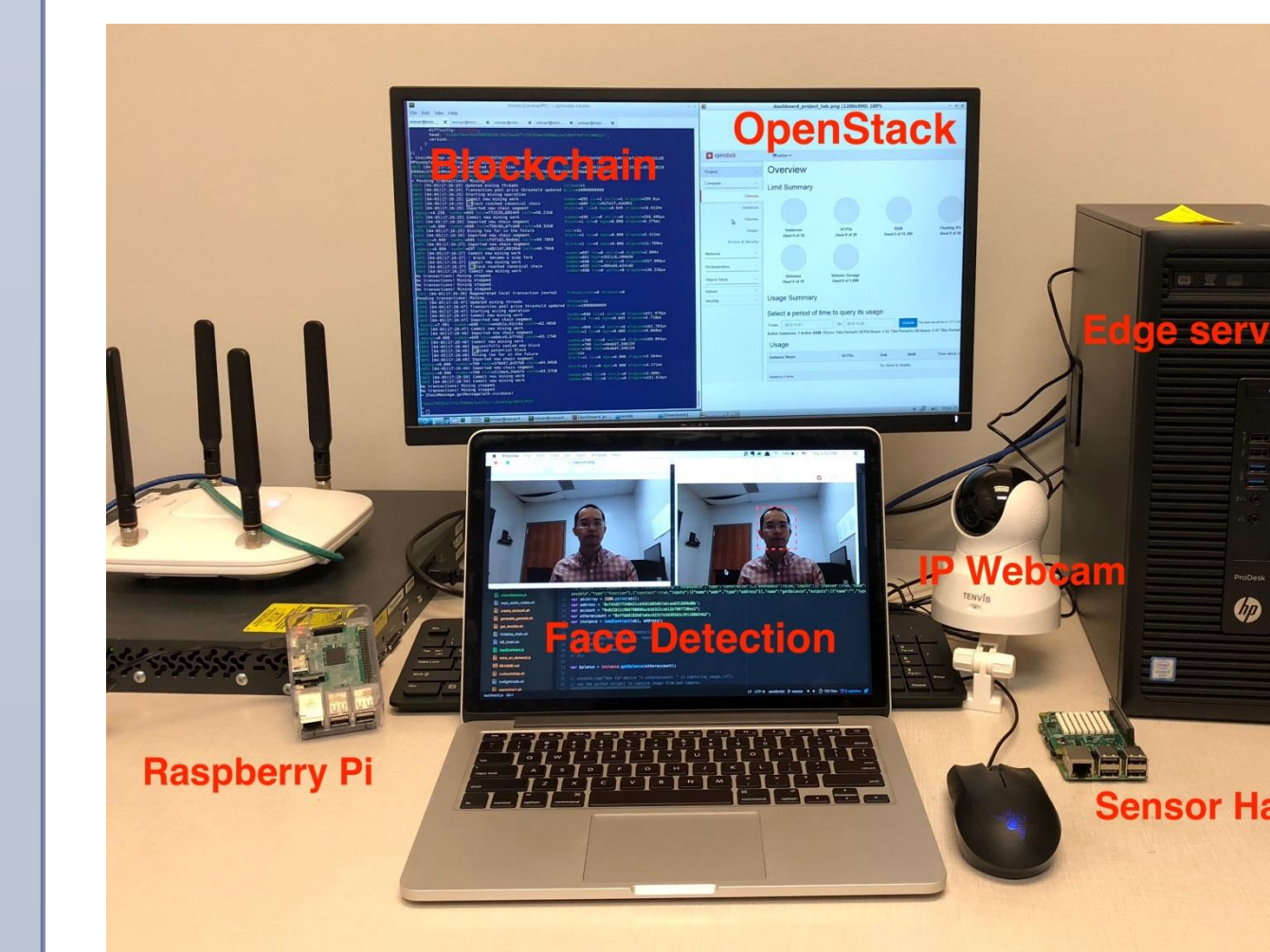


Figure 5. Testbed

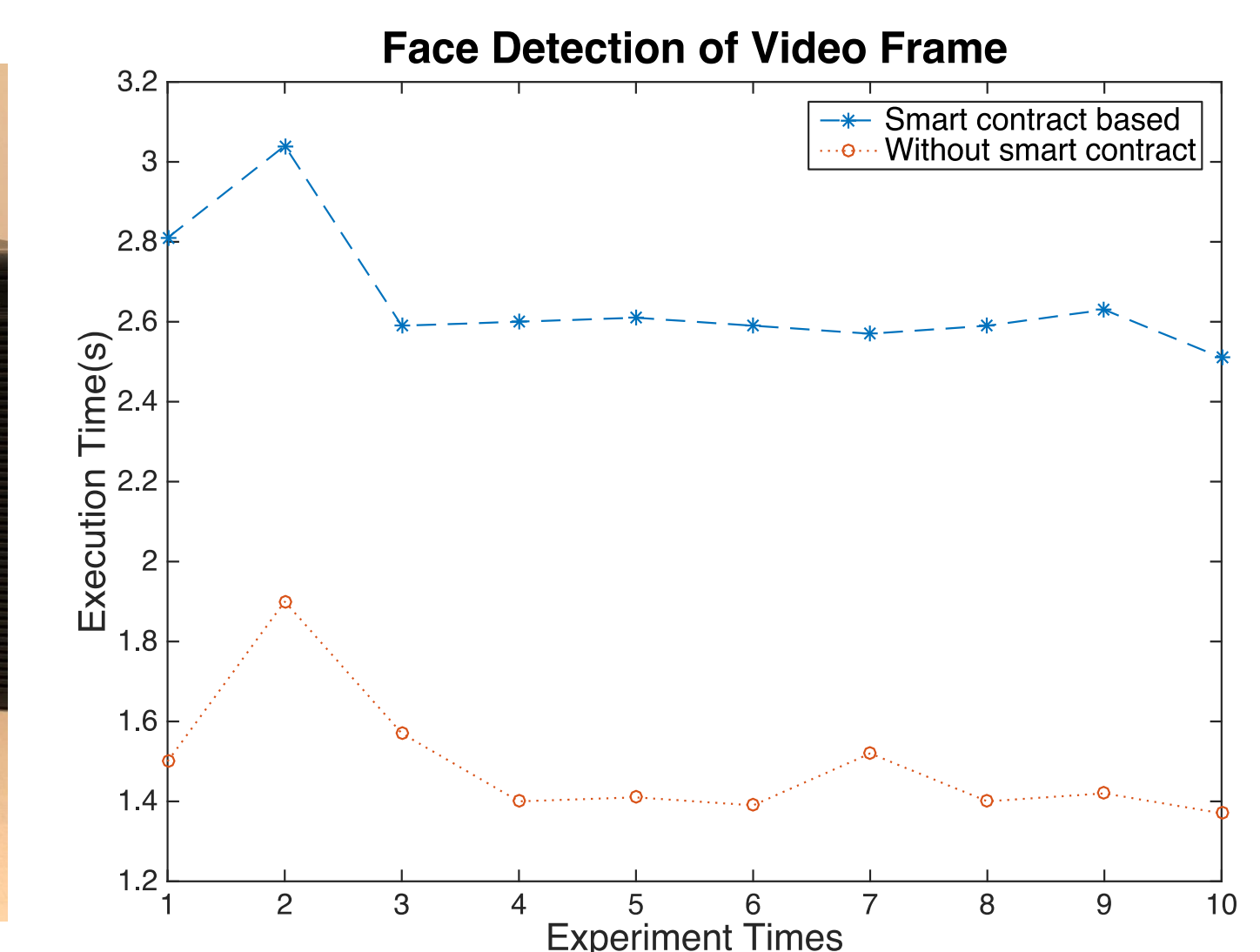


Figure 6. Overhead of Blockchains

Request ID	Account #	Balance	App Type	Priority	Last Activity	Behavior
1	0x822911c994790896acb3d322ceb12b7907730ea1	315	sensor	normal	1522940136.753401	normal
2	0xfdb8182b87a6ecb2317e3d36563c29116802462	1050	video	emergent	1522940160.072789	frequent

Table 1. Service Requests Example

Conclusions

- A Credit-Coin based edge resource management system is proposed using Blockchain and Smart Contracts technologies.
- Edge computing resources are allocated automatically based on request details, application types and history activities of IoT devices.
- All IoT activities and transactions are recorded on blockchain with data persistence, data traceability, and tampering resistance.

Ongoing and Future Work

- ❖ Integrate new findings and knowledge into new curriculum under development
- ❖ Use AI and machine learning to optimize resource usage and make smart decision
- ❖ Blockchain and smart contracts introduce new overhead for the Edge-IoT system. A lighter chain implementation is useful to improve the system performance.
- ❖ Deploy and test different types of IoT devices with different resource demands.

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