Blockchain-Based Software-Defined Industrial Internet of Things: A Dueling Deep Q-Learning Approach

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목차

Introduction

- BC-based consensus protocol to simplify and secure the collection and synchronization of net- work views between different SDN controllers
- A novel dueling deep Q-learning approach to learn the optimal strategy

Related Work

- SDN Architectures
  - Statically Configured Control Architecture
  - Dynamically Configured Control Architecture

System Model

- Network Model

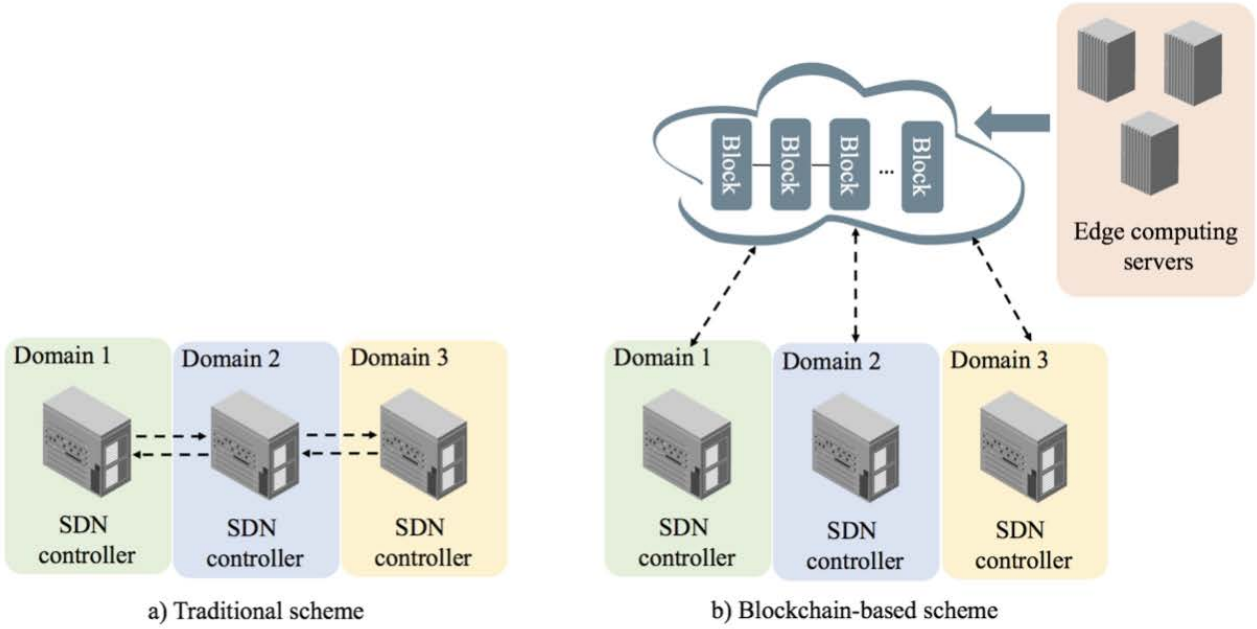


Fig. 1: The different network structures between traditional scheme and BC-based scheme.

System Model

- Trust Feature Model

$$\mathcal{K}^n(t) = [\kappa_{\mathcal{X}_s \mathcal{Y}_s}(t)]_{L \times L},$$

$$Pr(\delta^n(t+1) = \mathcal{Y}_s | \delta^n(t) = \mathcal{X}_s),$$

$$\Upsilon^c(t) = [\gamma_{\theta_s \phi_s}(t)]_{H \times H},$$

$$: Pr(\eta^c(t+1) = \phi_s | \eta^c(t) = \theta_s).$$

System Model

- Computation Model

$$CompR^e(t) = a^e(t)\frac{s_m}{t_m} = a^e(t)\frac{\zeta^e(t)s_m}{q_m},$$

BLOCKCHAIN-BASED CONSENSUS PROTOCOL

- Overview of BC-Based Consensus Protocol

TABLE I: The format of a transaction.

The number of this transaction in the block.
The Signature of this transaction.
The MAC of this transaction.
Payloads, including local events and OpenFlow commands.

TABLE II: The format of a block.

Field	Description
Version	Block version number.
Timestamp	Creation time of this block.
Controller ID	The identifier of this controller.
Block ID	The identifier of this block.
Block payload	Transactions in this block (Transaction #1, ..., Transaction #n).

BLOCKCHAIN-BASED CONSENSUS PROTOCOL

- Overview of BC-Based Consensus Protocol

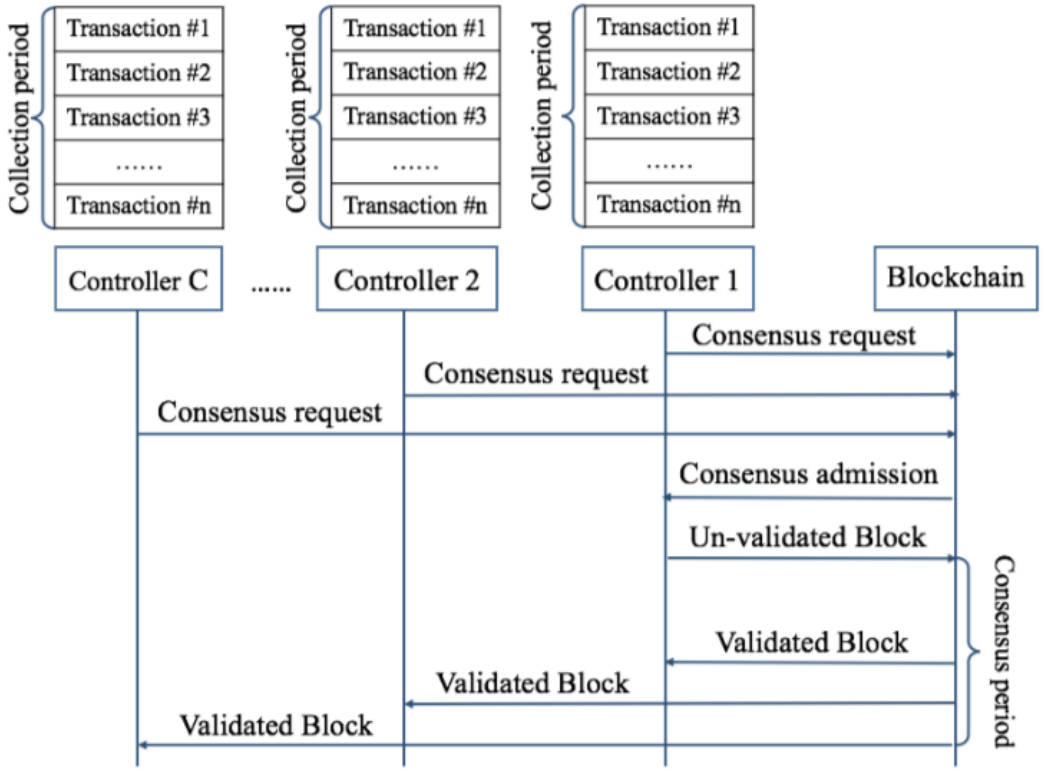


Fig. 2: The overview of consensus procedures in BC-based consensus protocol between different SDN controllers.

BLOCKCHAIN-BASED CONSENSUS PROTOCOL

- Detailed Steps and Theoretical Analysis

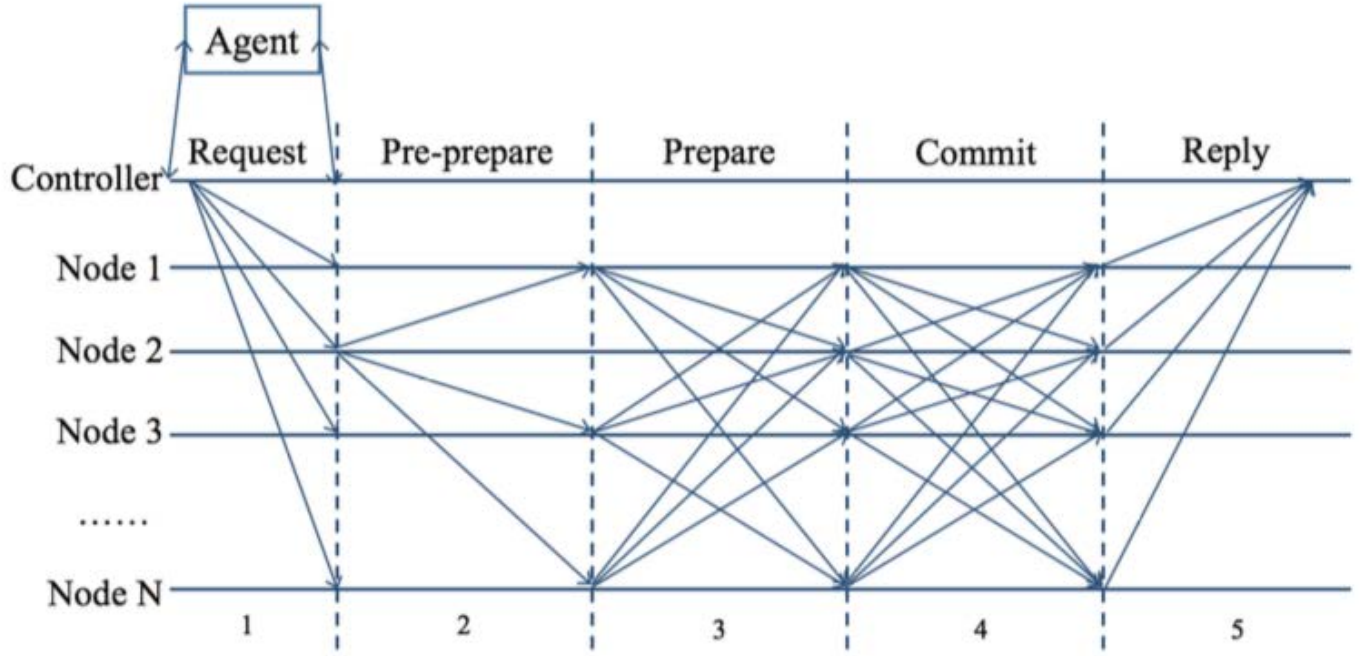
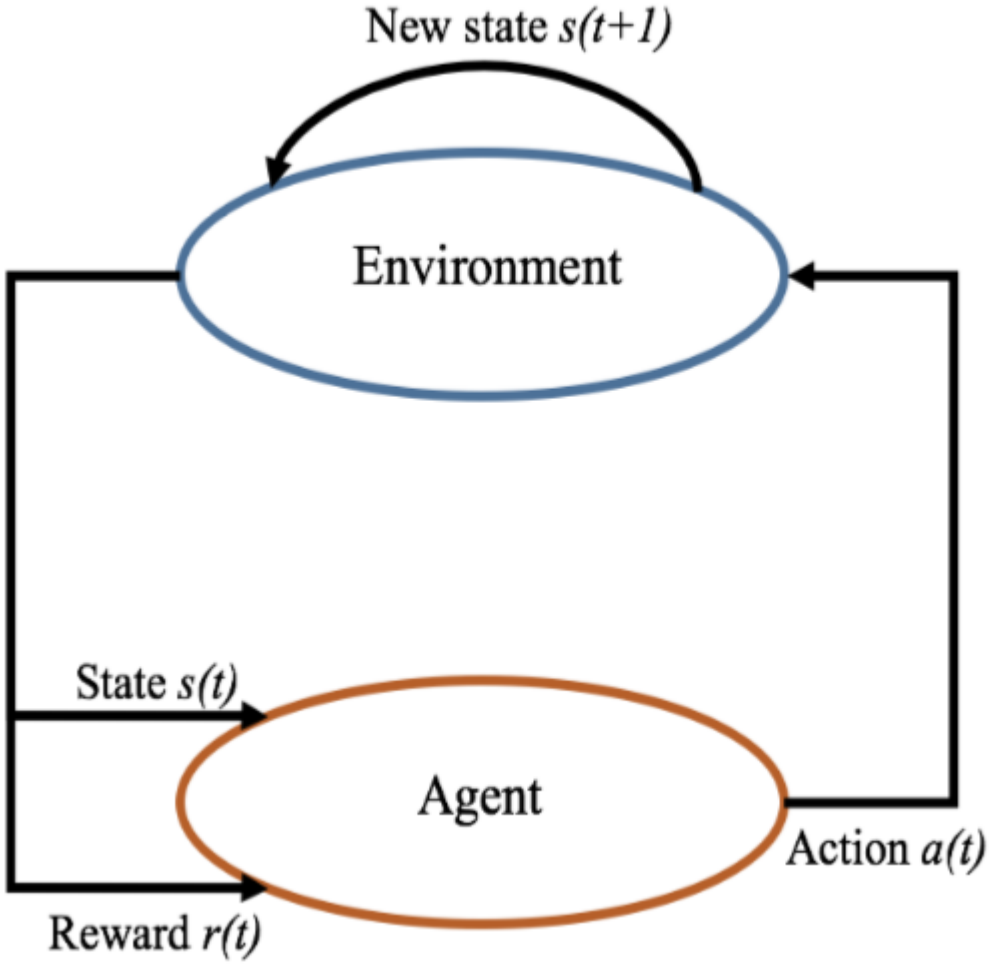


Fig. 3: The detailed procedures inside the permissioned BC.

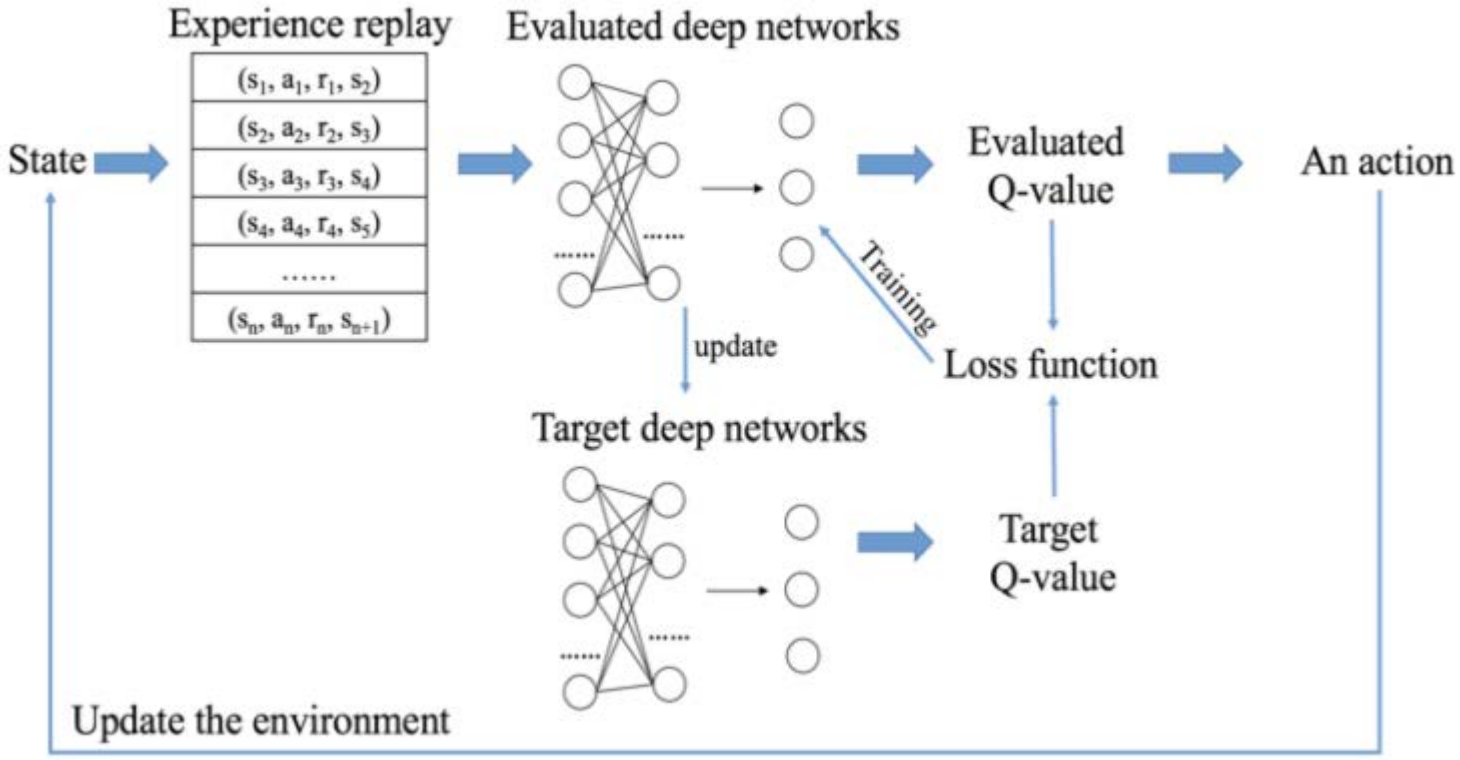
PROBLEM FORMULATION

- The interaction of the learning agent and the environment



DUELING DEEP Q-LEARNING

- The workflows of DQL



DUELING DEEP Q-LEARNING

- Dueling Deep Q-Learning Approach

Algorithm 1 Dueling DQL

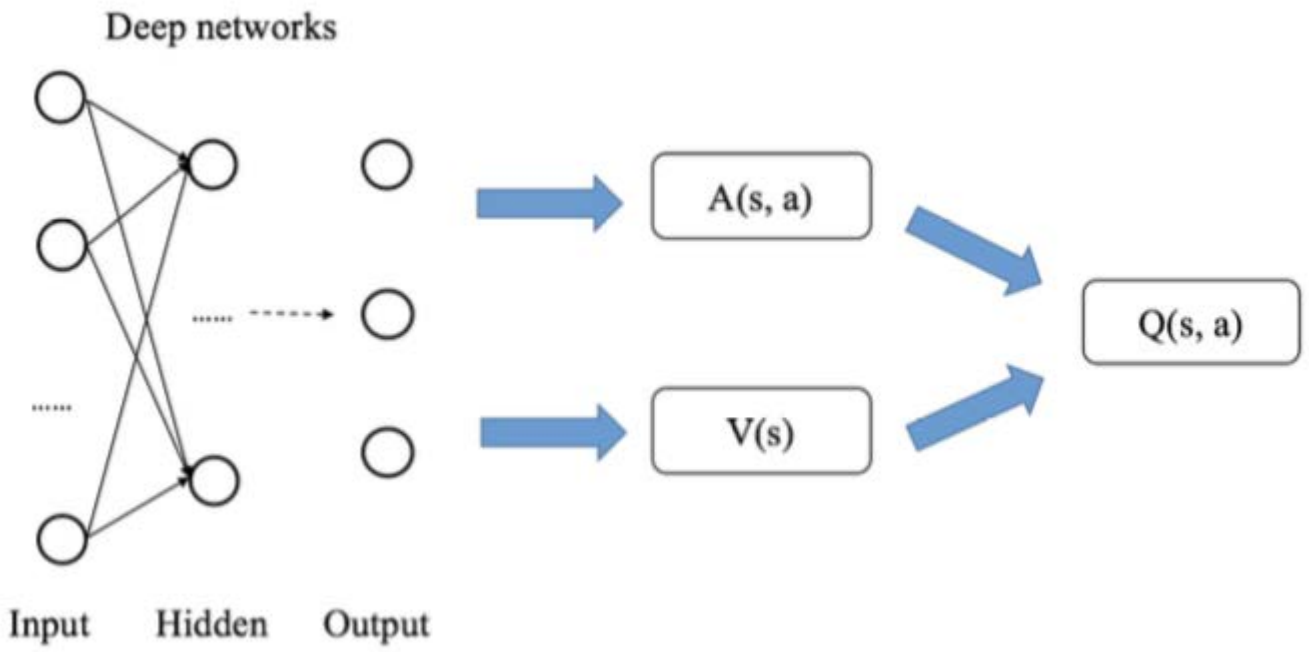
Initialization:
Initialize evaluated deep networks with weights and biases set ω.
Initialize target deep networks with weights and biases set ω^{-}.
for $k = 1 : K$ **do**
  Reset the environment with a randomly initial observation s_{ini}, and $s(t) = s_{ini}$.
  while $s(t)! = s_{terminal}$ **do**
    Select action $a(t)$ based on $\epsilon-$greedy policy.
    Obtain immediate reward $r(t)$ and next observation $s(t+1)$.
    Store experience $(s(t), a(t), r(t), s(t+1))$ into experience replay memory.
    Randomly sample some batches of $(s(i), a(i), r(i), s(i+1))$ from experience replay memory.
    Calculate two streams of evaluated deep networks, including $V(s; \omega, \varrho)$ and $A(s, a; \omega, \zeta)$, and combine them as $Q(s, a; \omega, \varrho, \zeta)$ using (25).
    Calculate target Q-value $Q_{target}(s)$ in target deep networks:
    if s' is $s_{terminal}$
      $Q_{target}(s) = r_s$,
    else
      $Q_{target}(s) = r_s + \gamma max_{a'} Q(s', a'; \omega', \varrho', \zeta')$.
    Train evaluated deep networks to minimize loss function $L(w)$

$$L(\omega, \varrho, \zeta) = E[(Q_{target}(s) - Q(s, a; \omega, \varrho, \zeta))^2]. \tag{23}$$

    Every some steps, update target deep networks.
    $s(t) \leftarrow s(t+1)$
  end while
end for

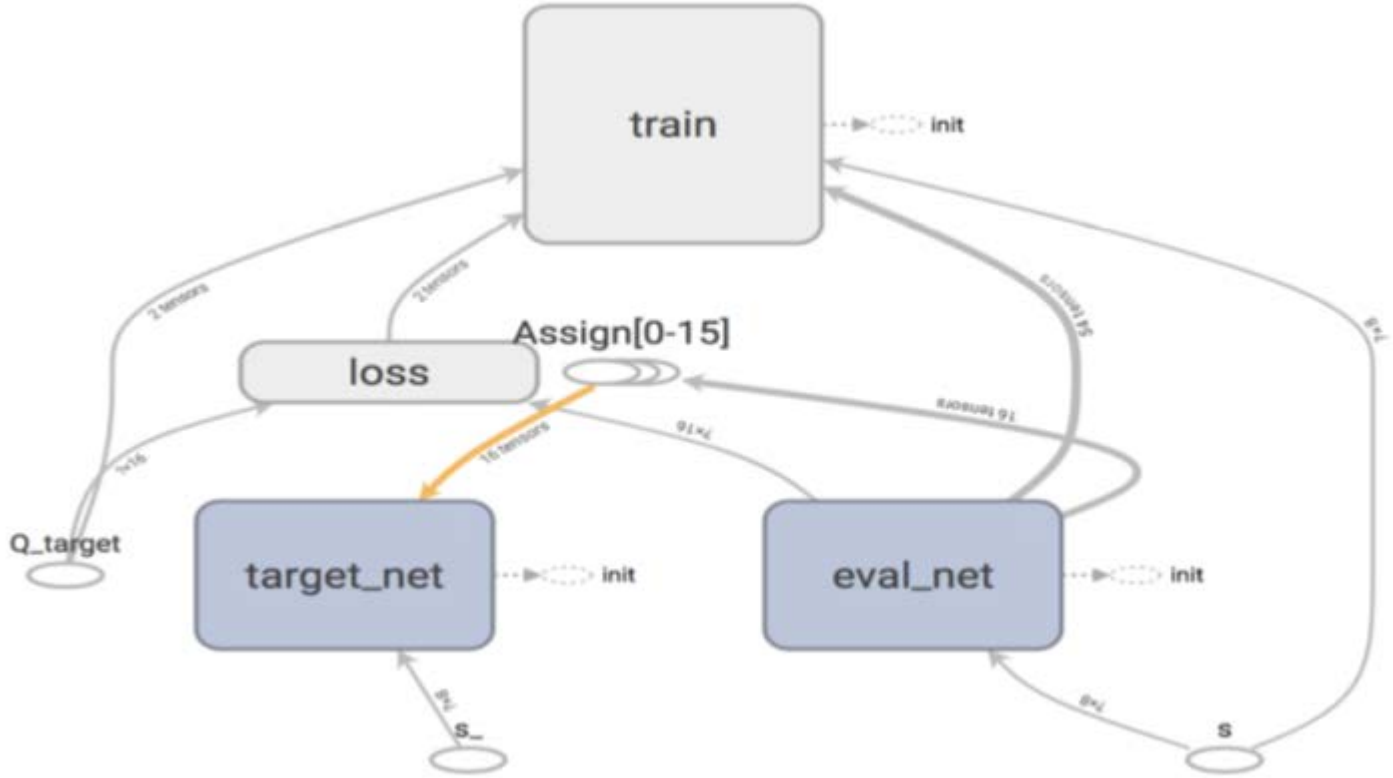
DUELING DEEP Q-LEARNING

- Dueling architecture



SIMULATION RESULTS AND DISCUSSIONS

- The visualized TensorFlow graph in TensorBoard



SIMULATION RESULTS AND DISCUSSIONS

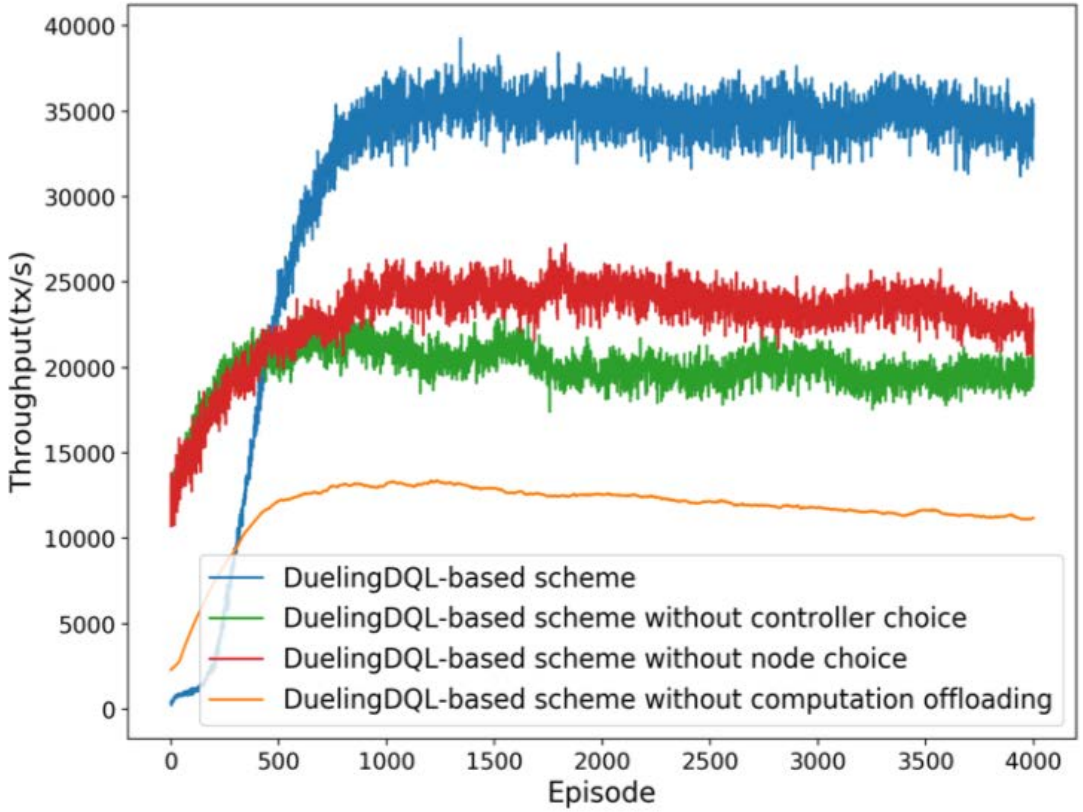
- Simulation Results

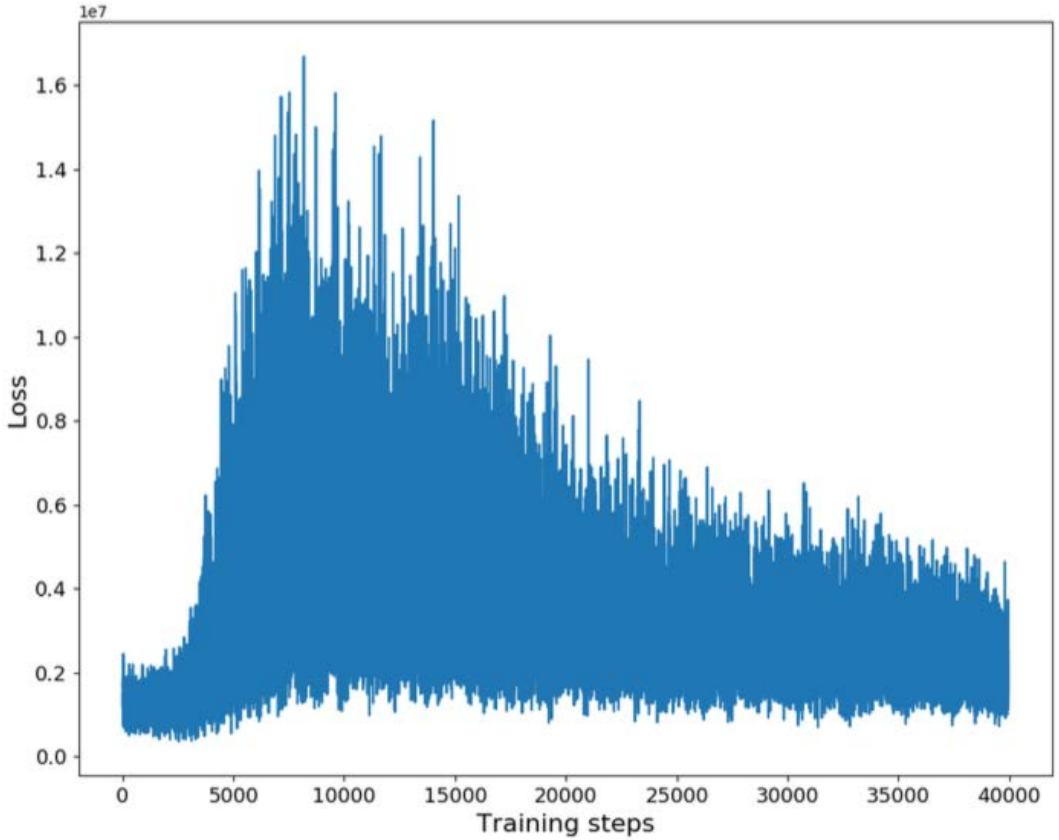
TABLE III: Parameters setting in the simulation.

Parameter	Value	Description
θ	8 Mcycles	The required number of CPU cycles to verify one signature.
α	0.05 Mcycles	The required number of CPU cycles to verify and generate one MAC.
b	1Mb	The batch size of a block.
γ	0.9	The discount factor.

SIMULATION RESULTS AND DISCUSSIONS

- Simulation Results





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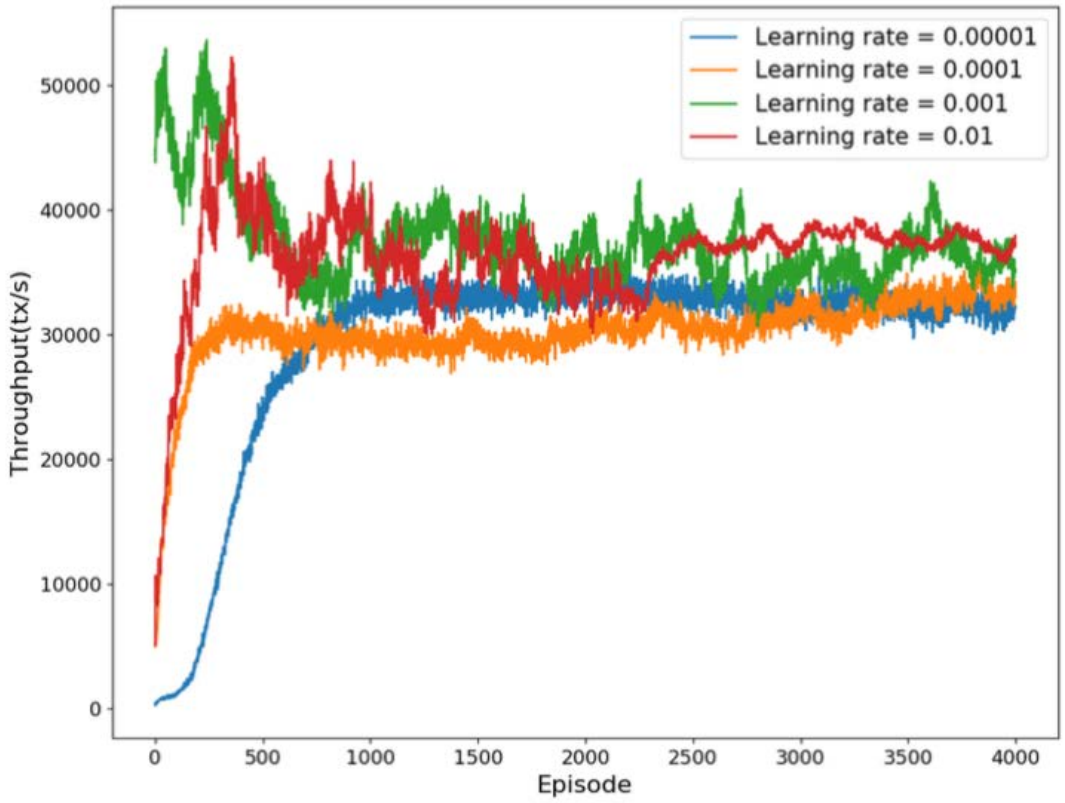

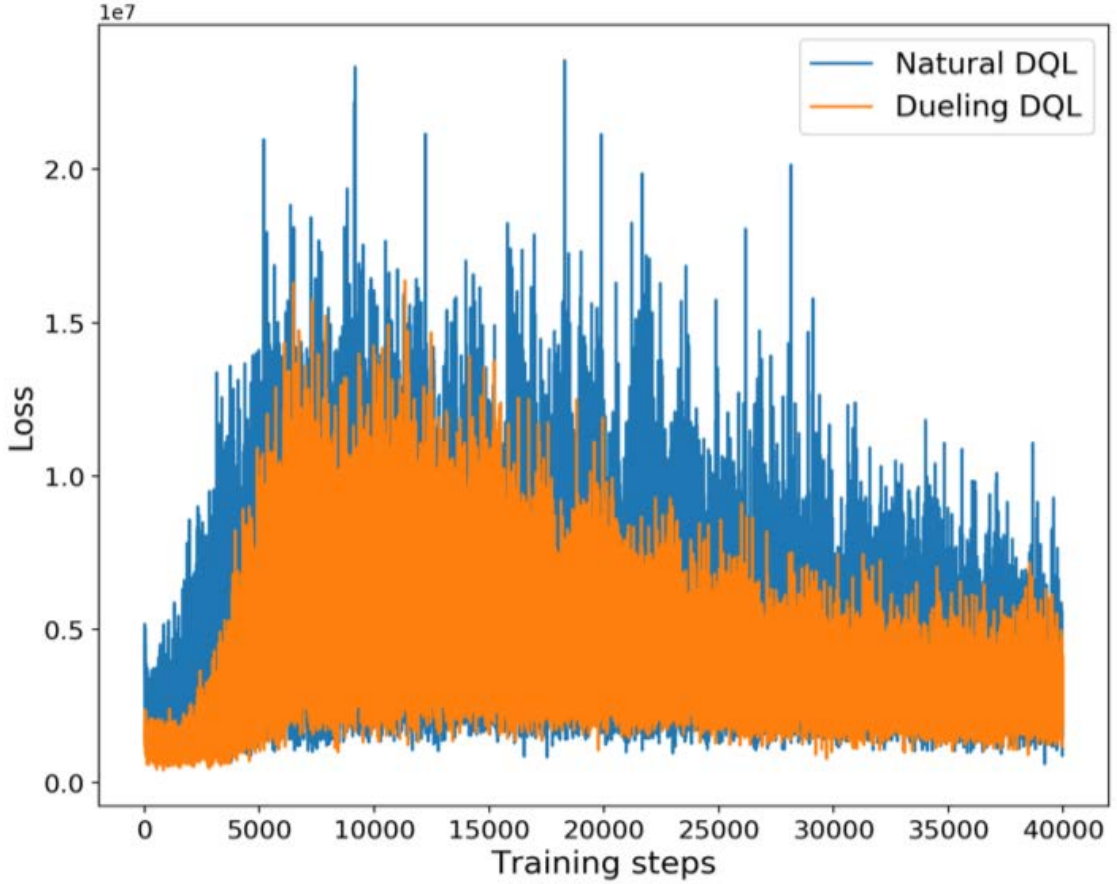

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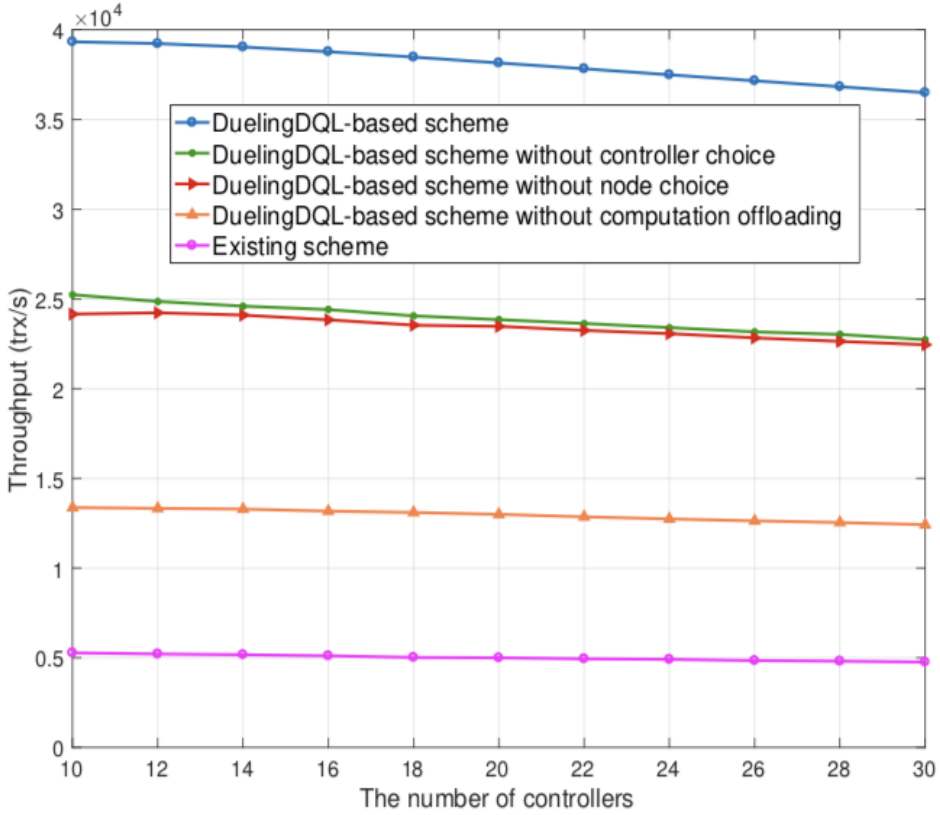

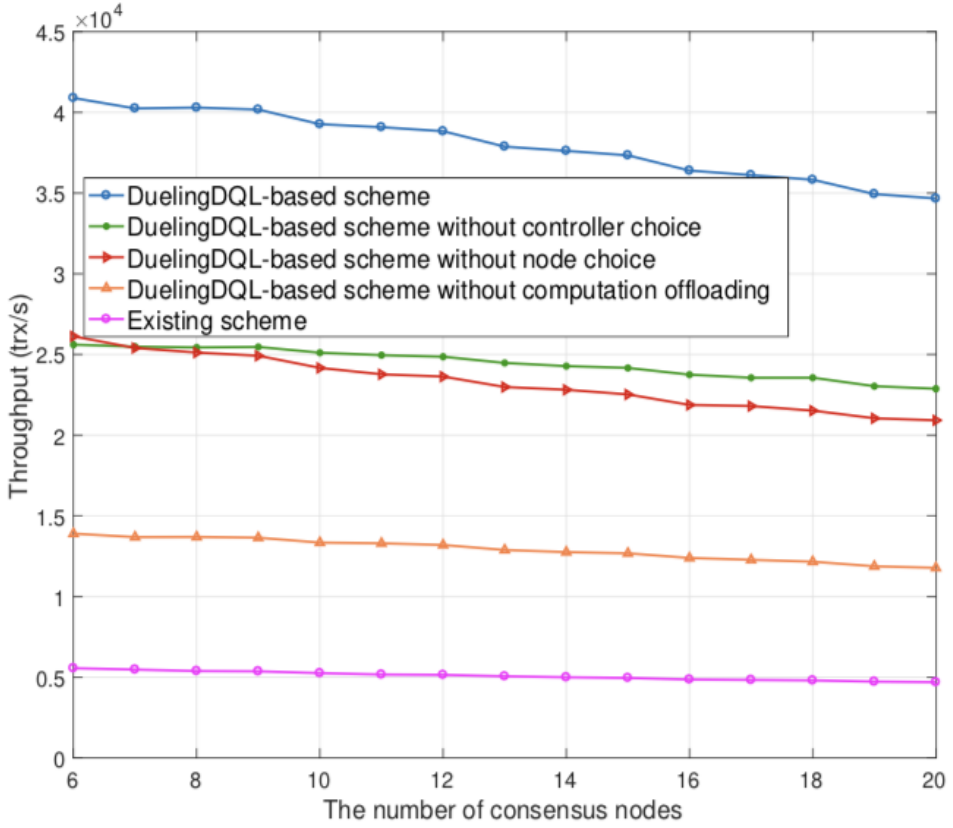

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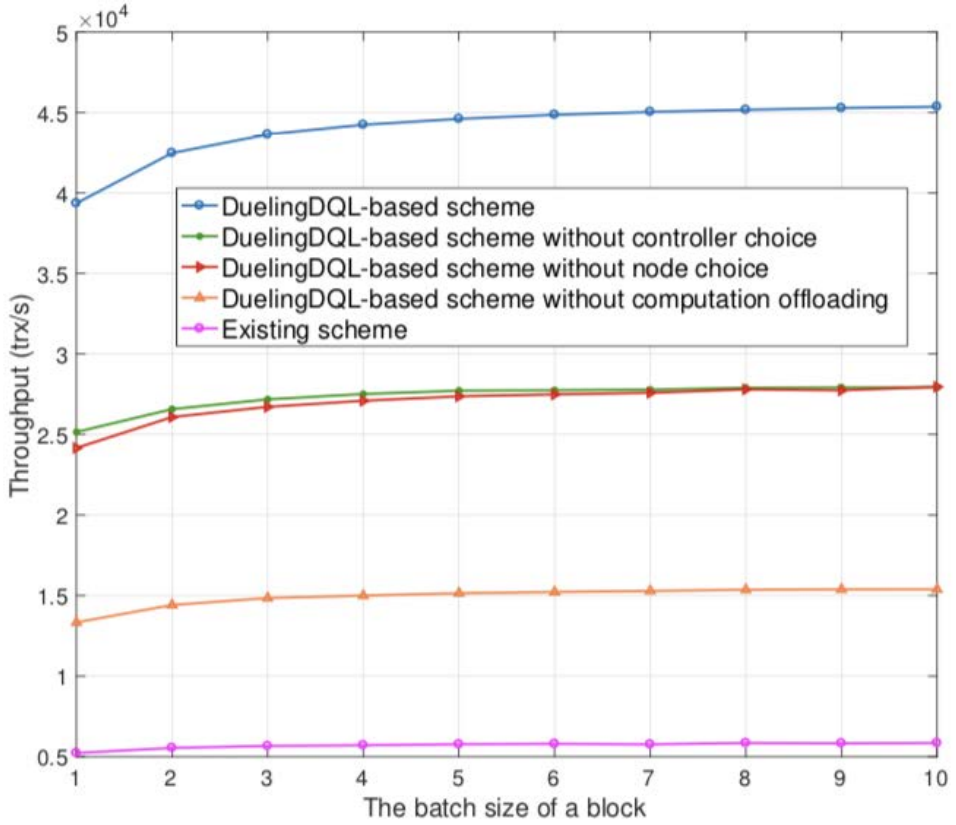

CONCLUSIONS AND FUTURE WORK

- Blockchain-based consensus protocol in distributed SDIIoT
- Considered the trust features of blockchain nodes and controllers, as well as the computational capability of the system
- Formulated view changes, access selection, and computational resources allocation as a joint optimization problem
- A novel dueling deep Q-learning approach to solve this problem