Position Prediction for Routing in Software Defined Internet of Vehicles

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Abstract—By the prediction of future location for a vehicle in Internet of Vehicles (IoV), data forwarding schemes can be further improved. Major parameters for vehicle position prediction includes traffic density, motion, road conditions, and vehicle current position. In this paper, therefore, our proposed system enforces the accurate prediction with the help of real-time traffic from the vehicles. In addition, the proposed Neural Network Model assists Edge Controller and centralized controller to compute and predict vehicle future position inside and outside of the vicinity, respectively. Last but not least, in order to get real-time data, and to maintain a quality of experience, the edge controller is explored with Software Defined Internet of Vehicles. In order to evaluate our framework, SUMO simulator with Open Street map is considered and the results prove the importance of vehicle position prediction for vehicular networks.

Index Terms—Vehicle to Anything (V2X), position prediction, SDN, edge controllers, internet of vehicles, GIS, neural network

I. Introduction

Nowadays, vehicles on the road are increasing exponentially and it is expected that the count will go beyond 2.5 billion by 2050s [1]. With the exponential growth of traffic, the complexity of traffic management propagates in parallel. Intelligent Transportation System (ITS) is hot research among the autonomous industry with its varying road safety and entertainment applications [2]. The study of the connected car is one of the key research area and is being evolved under the umbrella of the Internet of Vehicles (IoV) [3], [4], a sub-field of Internet of Things (IoT). The main focus of IoV is V2X communication, i.e. vehicle to everything (vehicle to infrastructure, vehicle, pedestrians, network gateways, and RSUs communication, etc. [5], [6]). V2X communication is considered as one of the vital technology explored by ITS for traffic assistance in a smart city. V2X communication consists of Dedicated Short Range Communications (DSRC) or cellular infrastructure, based on its requirement to their respective scenarios. However, a combination of both the technologies can also deliver promising results with high throughput and low latency for critical applications [7]. [8].

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In the past few years, vehicle to vehicle (V2V) communication gain a lot of attention because of its potential to make our journey comfortable on the roads. The core requirement of connected cars include a reliable and fast communication with very low latency response to and from a service provider. In the meanwhile, it needs to be more efficient to manage a huge number of requests simultaneously with no traffic congestion. In ITS, a vehicle on the road always initiates a new connection request towards the traffic controller in case of path failure. Traffic controller estimates a new path each time it receives a path failure request using different protocols. This way of calculating a new path creates an extra overhead, results in more delayed traffic. Furthermore, due to link failure the packet drop ratio increases, hence an optimized framework with efficient routing protocol is needed to overcome these problems.

A variety of solutions have been proposed so far to overcome these limitations due to poor connectivity, less flexibility, less scalability, and no intelligence in vehicular networks [9]. Nowadays, Software-Defined Networking (SDN) approach is at its peak in almost every computer network field. SDN is a new revolution in which a control plane is separated from the data plane. Data plane in SDN accommodates dumb forwarding devices from different vendors while the control plane is known as the brain of the network where its intelligence lies.

To overcome the problems in the field of IoV, SDN comes into play with its full flexibility and scalability from the wired network [10]. Centralized SDN approach provides better resource management and a bird eye view over vehicular networks in the data plane [11], [12]. With the exploration of all these powerful techniques, still the problem of network overhead caused by path failure packets exists, hence, a better routing mechanism is required to estimate stables paths, which is the motivation for this paper.

In this paper, an Efficient Routing Algorithm (ERA) is proposed for SDN-IoV along with the edge controllers to gain the benefits of centralized as well as decentralized data packet handling. Furthermore, ERA is responsible to estimate shortest but stable paths between the vehicles by a prediction of vehicle future position. In order to do that, a position prediction model is trained by means of a Neural Network. The prediction model is trained based on data from the vehicles, i.e., vehicle moving speed, direction velocity, road_id, and edge_id, etc. This future location prediction of a moving vehicle plays a significant role in making the routing system more efficient.

The rest of the paper is organized as follows: Section II describes the related work of Software Defined Internet of Vehicles SDN-IoV. Section III present our proposed architecture in detail. Section IV shows the implementation details and experimentation environment of our system. Section V shows the simulation results. Section VI concludes the work.

II. Related Work

SDN is a revolutionized network design in which the main idea is to partition the network control from forwarding devices. It provides centralized control and makes a network simple. The SDN networking paradigm grants many advantages compared to old-style distributed approaches. On a centralized control plane, one can deploy standard as well as customized protocols to configure network devices. Customization of the protocols over the network assists researchers to deploy and visualize the updated protocols.

A number of researches have been done previously in the SDN paradigm, as shown in Fig. 1, and its integration with the Internet of Vehicles [9], [11], [13]-[15], as shown in Table I.

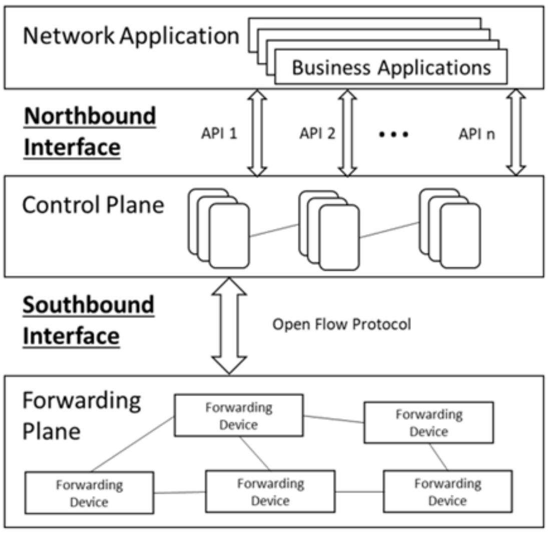

Fig. 1. Software defined architecture

TABLE I: Literature Comparison

Literature	SDN	Digital Map	Edge/Fog Concept	Position Prediction
[9]	✓	×	✓	×
[13]	✓	✓	×	×
[11]	✓	×	×	×
[14]	✓	✓	✓	×
[15]	✓	✓	×	×
[16]	✓	×	✓	×
ERA	✓	✓	✓	✓

Authors in [15] proposed another SDN based Vehicle Ad-Hoc on-demand routing protocol (SVAO). The protocol works at two different levels: a global level by distributed controllers i.e. RSUs, etc., and a local level consist of vehicles on the road. Roads are further divided into non-overlapping road segments. Optimal paths are calculated between the road segments at the global level, paths inside the road segment are estimated by the local vehicles. Authors in [11] proposed SDN based architecture to support vehicular networks. Using the network topology information, the SDN controller finds new paths between the source and the destination. However, in case of SDN failure, vehicle nodes switch to GPSR protocol for their normal operations of packet forwarding. SDN based framework is proposed in [16] for efficient delivery of data packets in VANETs. The optimized path is calculated globally by the controller to relay the traffic through shortest and low routing overhead paths. Another contribution of the paper is to have two centralized protocols: carry and forward approach and multi-hop forwarding approach, for different scenarios.

Authors in [13] proposed an SDN-based geo-routing protocol (SDGR) for VANETs. This paper focuses on geographic routing which only takes the local information into account to forward a packet which promotes further the problem of sparse connectivity local maximum. Two algorithms are explored in their approach: efficient forwarding path and packet forwarding. Every vehicle transmits state messages to the server and server updates the vehicles state in a vehicular network. In the proposed algorithm, in order to update the vehicle state on the road, every vehicle periodically transmits a message. Source vehicle directly sends the packet if the rules are installed for the destination into its flow table against the incoming packet. However, in the opposite case, a request is transmitted towards the controller which calculates an optimal path between two nodes using a well-known Dijkstra's algorithm. The algorithm is endorsed to discover a path with high forwarding progress towards the destination and minimum hops. In order to avoid sparse connectivity, the proposed algorithm also considers the vehicle density parameter on the road. An optimal path between source and destination is then sent back to the source vehicle by the controller. After getting a reply, vehicle add this path into the packet header, and the packet is forwarded accordingly. Next hop is selected using the forwarding algorithm until a packet reaches its destination.

Centralized SDN control is considered to be more efficient in most of the scenarios, but in the other scenarios, decentralized management is preferred. Authors in [9] and [11] proposed decentralized SDN architecture for vehicular networks with more optimized resource consumption. Local SDN controllers are considered to be deployed at base stations. This is because the vehicles on the road require service availability with improved communication using the routing protocols with no delay. Therefore, a concept of Fog Computing [9] is combined with the SDN controller to provided critical and delay sensitive applications on time.

To this end, SDN based routing protocols proposed so far, hardly consider the effect of vehicle position prediction on the performance of the network as well as the controller. Therefore, in this paper, we are focusing on vehicle future location prediction. Our proposed model predicts a vehicle future location using neural networks. Edge controllers are responsible to have real-time traffic from the vehicles for future position estimation locally and a request is forwarded towards the SDN controller if the destination is out of range.

III. Proposed Solution

This section of the paper describes our proposed architecture and all of its components in detail. An SDN based framework is proposed to provide a stable path for IoV by predicting a vehicle position in the future, as shown in Fig. 2. The control plane consists of a centralized SDN controller and several edge controllers. Data plane consists of several Road Side Units (RSUs) and vehicles, and are considered as Open Virtual Switch (OVS). OpenFlow (OF) Protocol acts as a bridge between the control and data plane and provides the communication link between controller and OpenFlow enabled devices. In a control plane, all edge controllers are connected with SDN controller through a high bandwidth internet. Moreover, each EC consists of several modules; Input Manager (IM) is responsible for retrieving data from the OpenFlow Agent plugin and filters it in a predefined format. Synchronizer module synchronizes the data into a distributed topology table, which consist of the current real-time updated vehicle information, like position, direction, velocity, and acceleration. Every EC has its own distributed topology table and responsible to keep the vehicle information of its own vicinity. Since, it is assume that a certain number of base stations are manages by each EC, vehicles will be able to share information to their respective ECs only.

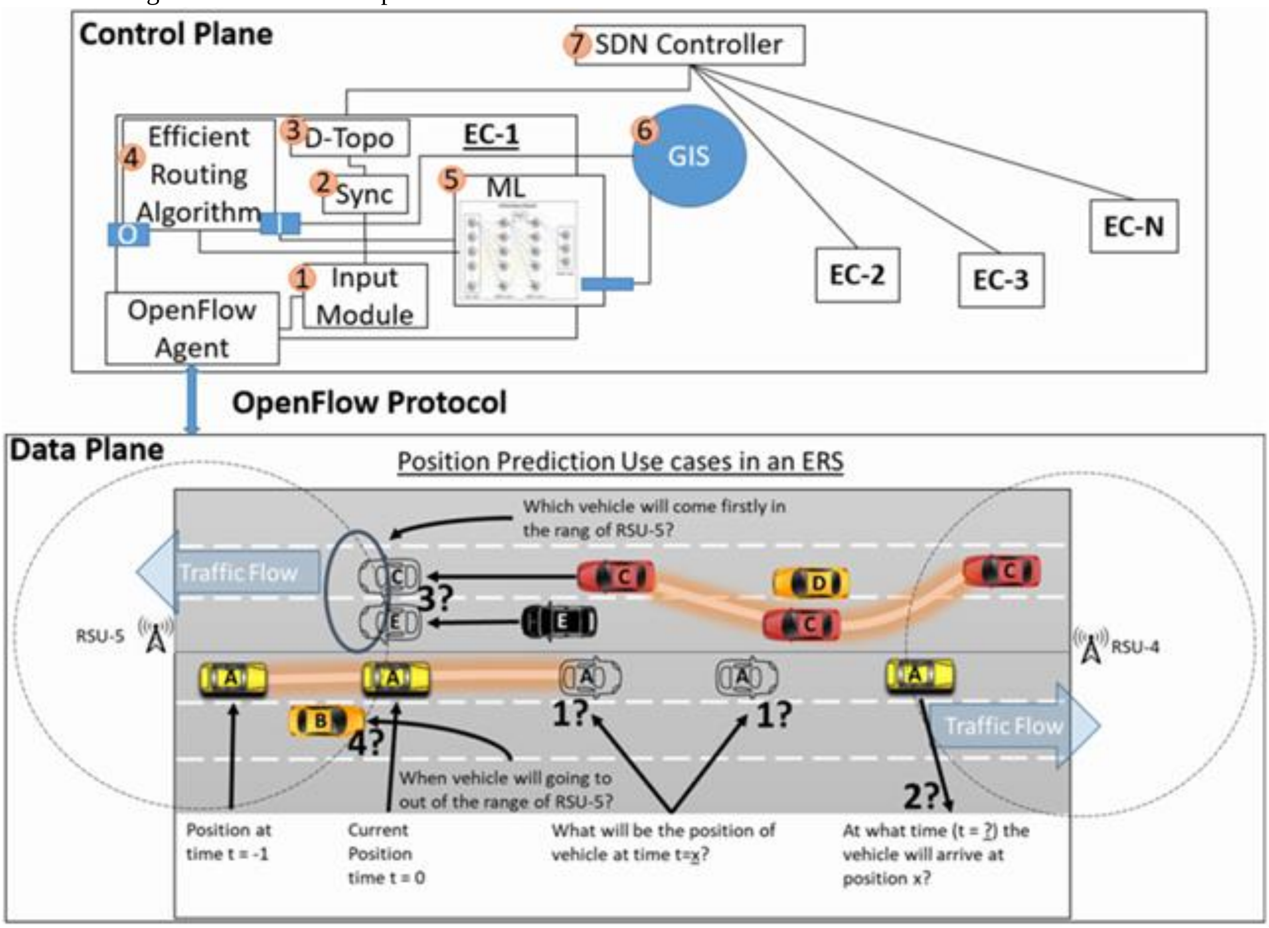

Fig. 2. The proposed architecture for efficient routing system

The Routing Module (RM) is the core of the whole system and is liable to generate the optimized end-to-end path. This module communicates with all the other modules, along with that, it gets the information of vehicles from the topology table and identifies the current positions of vehicles, speed, direction, and some other parameters. This routing system uses the Machine Learning Model (MLM) to predict a vehicle position using Neural Network model. RM also communicates with a Geographical Information System (GIS) to have road information in advance. RM then get the end-to-end paths based on a number of hop counts and create the list in ascending order. After creating the list, RM calls the MLM functionality by sending the paths with details of every vehicle in the selected path.

MLM module predicts a position and the predicted results are sent back to the RM module, where the future network topology is estimated. RM also checks and calculates the path connectivity and a duration path, respectively. If the lifetime is more than the threshold value of stability then it selects the path, otherwise, the RM again applies the same technique to the next selected path from the list of shortest paths. After the calculation of shortest and stable path, RM module further installs the flow rules into the flow tables of respective vehicles and RSUs only, which are included in the selected path.

Each EC is responsible for covers a specific area in order to receive the data to reduce the network traffic overhead. So in our case, each EC communicates with only 8-10 RSUs. Whenever there is a request for a new path, EC first checks its database for destination vehicle and a shortest and stable path is estimated towards it. A request is forwarded to SDN controller in case of destination vehicle is out of EC's range. SDN has the whole network topology table, so SDN can calculate the end-to-end path in an efficient way. Moreover, the introduction of EC is more helpful in controlling the data traffic in real-time as well as it reduces the number of requests sends from vehicles to the SDN controller.

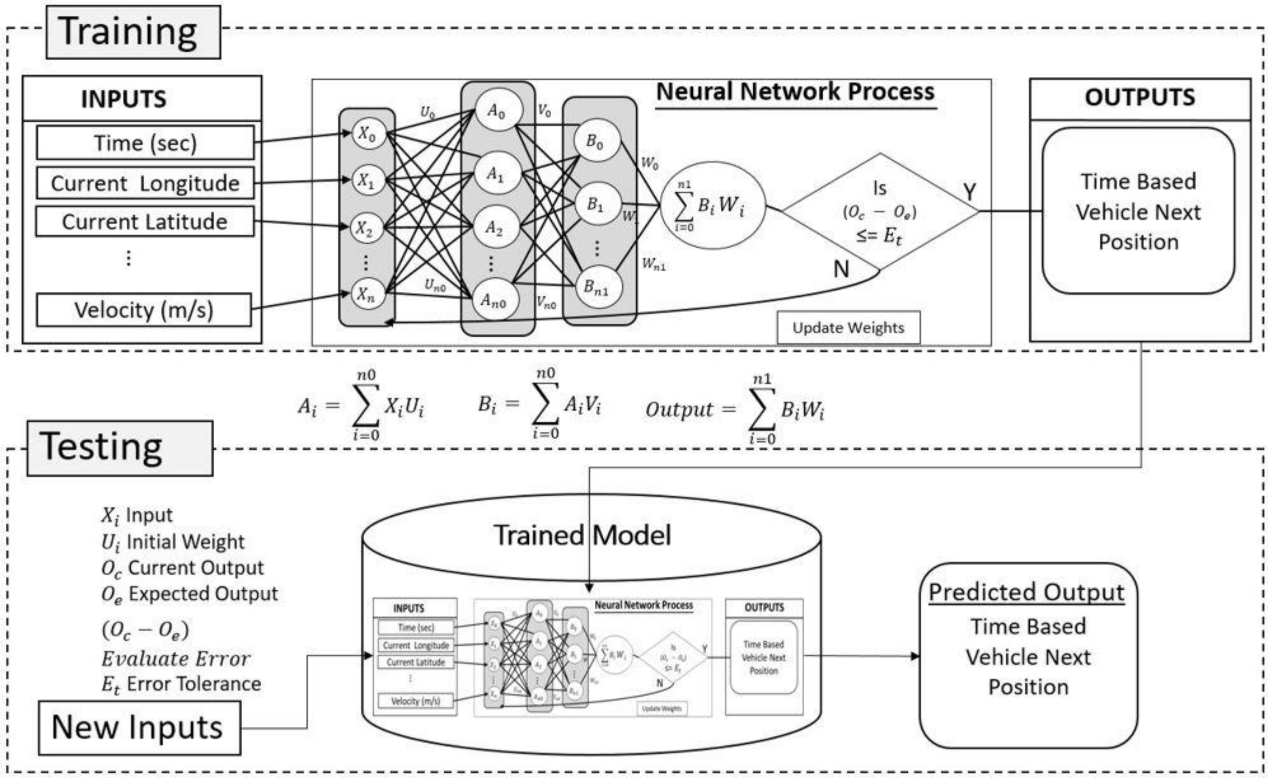

Fig. 3. Neural network model for proposed efficient routing system

In our proposed architecture, Machine Learning Module plays a key role for predicting the vehicle position. Fig. 3 shows the proposed MLM internal architecture for our routing system. For the sake of position prediction, Artificial Neural Network (ANN) is explored. ANN is a network of connected artificial neurons, which are organized in layers. There are three types of layers: input layer, output layer and several hidden layers between them. In each layer, there are different number of neurons are available during the training. Neurons in the hidden layers update their weights arbitrarily to get an optimized weights where the error is minimized. Once a model is trained completely, it could be used further with new sets of input to predict the vehicle future position on road. With the aim to provide improved prediction, different models for each edge controller are trained to their respective area only. This is because each trained model focuses only to a certain area according to its traffic and its behavior, results in better position prediction.

IV. Experimental Results

To evaluate our proposed solution the test scenario and results are presented in this section of the paper.

A. Simulation Setup

To simulate the system, we used a Virtual Machine (VM) in virtual box, with the specification of 12 GB RAM and 4 Processors. Two network adapters are used, first as a NAT which provides internet facility within the VM and second as a Host-only adapter is used to provide the communication between the other VMs and programs which are not in the same VM.

To perform the simulations, Jeju city map with main highways (map.osm) is exported from the Open Street Map (OSM) [17] to cover an area of (3000meter x 3500meter). By using NETCONVERT we import digital road network from map.osm and generate SUMO-road network jeju.net.xml [18]. Then we used a python script to randomly generate the traffic routes by using randomTrips.py script provided in the SUMO tools by SUMO organization which generate random traffic it assign randomly speed, direction and routes so we have the environment near to more real. The next step is to link the SUMO with MININET-WiFi to control the mobility and sync with the network topology. ONOS controller [19] is used with the ERA for controlling the whole process.

The network simulation parameters used in our system, i.e. vehicle velocity, transmission range, packet interval, and channel capacity, etc., are shown in Table II.

TABLE II: TEST SIMULATION DETAILS

Parameters	Values
Simulation time	500 sec
Number of vehicles	200
Vehicle velocity	5 to 25 m/s
Acceleration	0.3 to 1.25 m/s^2
Map Size	3000m X 3500m
Channel Capacity	5.8 GHz
Vehicle Transmission Range	200 meters
RSU Transmission Range	500 Meters
Hello Packet Interval	0.1 to 1 sec
Packet Size	512 bytes

B. Test Scenario

To give the proof of concept we use the test scenario where we used simple topology we used only two edge controller with one SDN controller in control plane both edge controllers are connected with the centerlized SDN controller through high bandwidth internet. In the data plane, we used vehicles and RSUs both treated as OVS.

C. Simulation Results

1) *Packet delivery ratio and vehicle speed*: Fig. 4 represents the Packet Delivery Ratio (PDR) and the effect of vehicle speed on it. It can be observe from figure that the PDR decreases with the increase in vehicle speed for the compared protocols (AODV, GPSR, and SDGR). In AODV, routes are maintained on demand. Each time a vehicle have a packet to deliver, a route request is forwarded in order to find a new path. Same is the case for path failure which results in less packet delivery ratio. GPSR and SDGR performs better when compare to AODV which is due to the installation of flow rules by SDN controller. However, it can be seen from the figure that ERA outperforms the other protocols even when the vehicle speed increases.

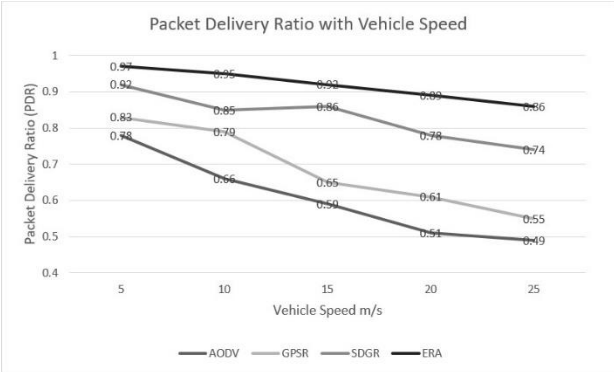

Fig. 4. Packet delivery ratio w.r.t vehicle speed

2) *Packet delivery ratio and vehicle density*: Fig. 5 shows the result of PDR with an increased number of vehicles. From the figure, it can clearly perceive that all other routing protocols provide better PDR when the number of vehicle increases and when compare to AODV. However, ERA shows more packet delivery ratio than AODV, GPSR, and SDGR. This is because the In ERA, SDN controller selects neighbor vehicles with relative velocity almost equals to zero and also the flow rules after vehicle position prediction improves the packet delivery up-to a large extent.

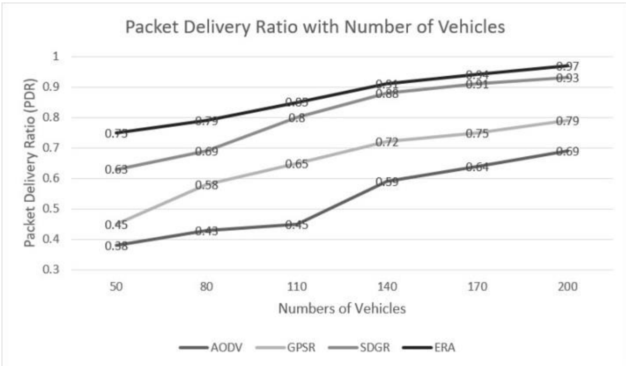

Fig. 5. Packet delivery ratio w.r.t number of vehicles

V. CONCLUSION

In this paper, a position-based Efficient Routing Algorithm (ERA) is proposed, capable of providing a stable path by predicting the vehicle position in SDN based Internet of Vehicles (SDN-IoV). Our proposed framework consists of different control and data plane modules to assist position prediction and routing in SDN-IoV. The simulation results show that our proposed system performs better with intelligent flow rule installation in advance while reducing the control message overhead and improved packet delivery ratio. Last but not least, the focus of our future work is to consider additional vehicle mobility scenarios to improve prediction accuracy.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Muhammad Ali Jibran and Muhammad Tahir Abbas conducted the research, Adeel Rafiq set the test-bed for ONOS controller. Muhammad Ali Jibran designed and developed the controller-based application named as ERA. Paper is written by Muhammad Ali Jibran and Muhammad Tahir Abbas. All of the work is done under the supervision of Professor Wang-Cheol Song. All authors had reviewed and approved the final version of the paper.

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