



行動計算與寬頻網路實驗室 Mobile Computing and Broadband Networking Lab (MBL) Introduction

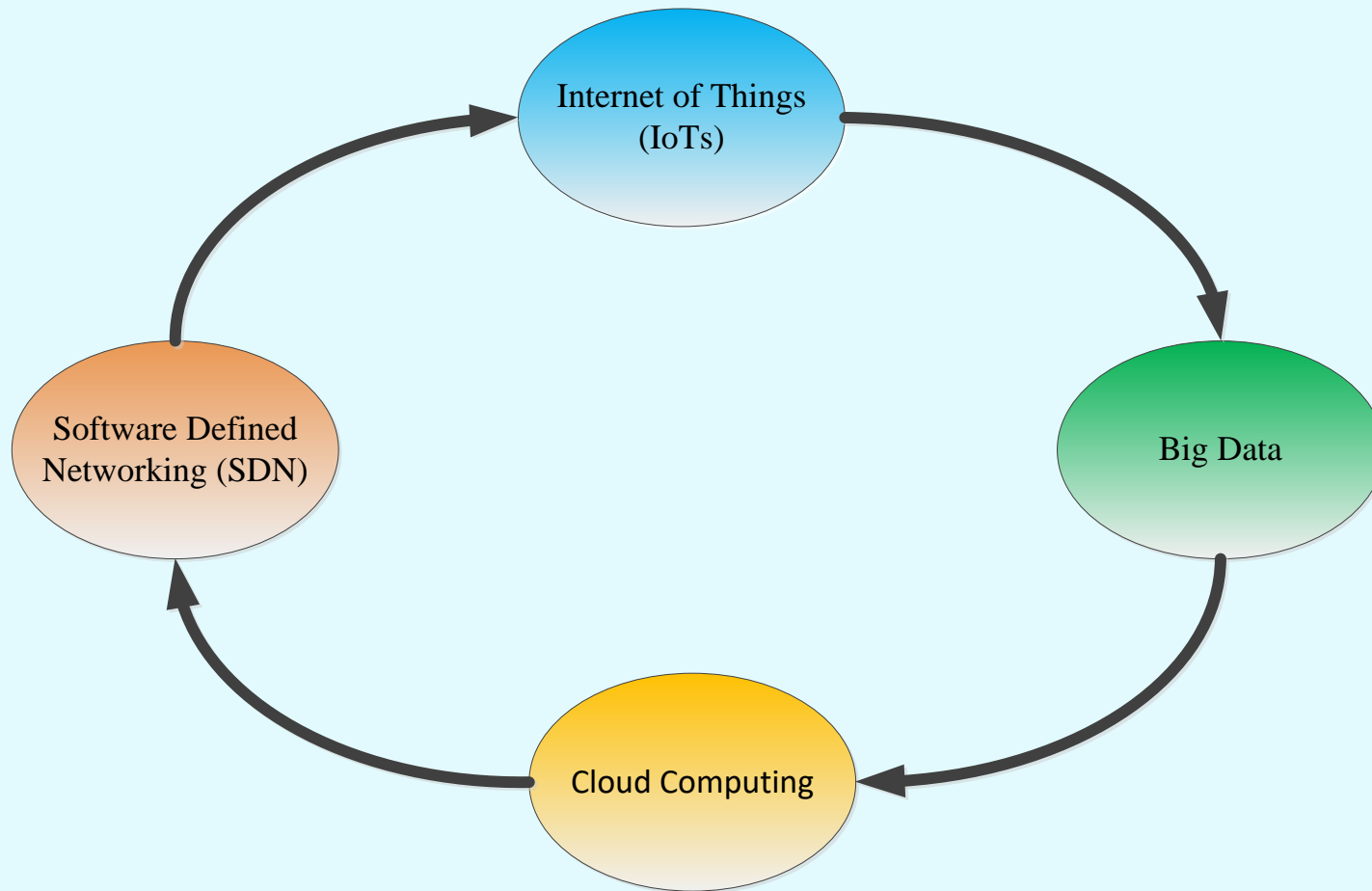
2016 – 2017

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Current Research Areas and Interests

- **Software Defined Networking**
- **Internet of Things**
- **Big Data Analytics**
- **Heterogeneous Networking**
- **Cloud Computing**

Research Areas: Closely Related



(Source: <http://newsroom.cisco.com/video/1170801>)

Recently Completed Projects

SDN Multiple Controllers: Synchronization, Hierarchical SDN Architecture and Security Issues (思銳, 科技部)

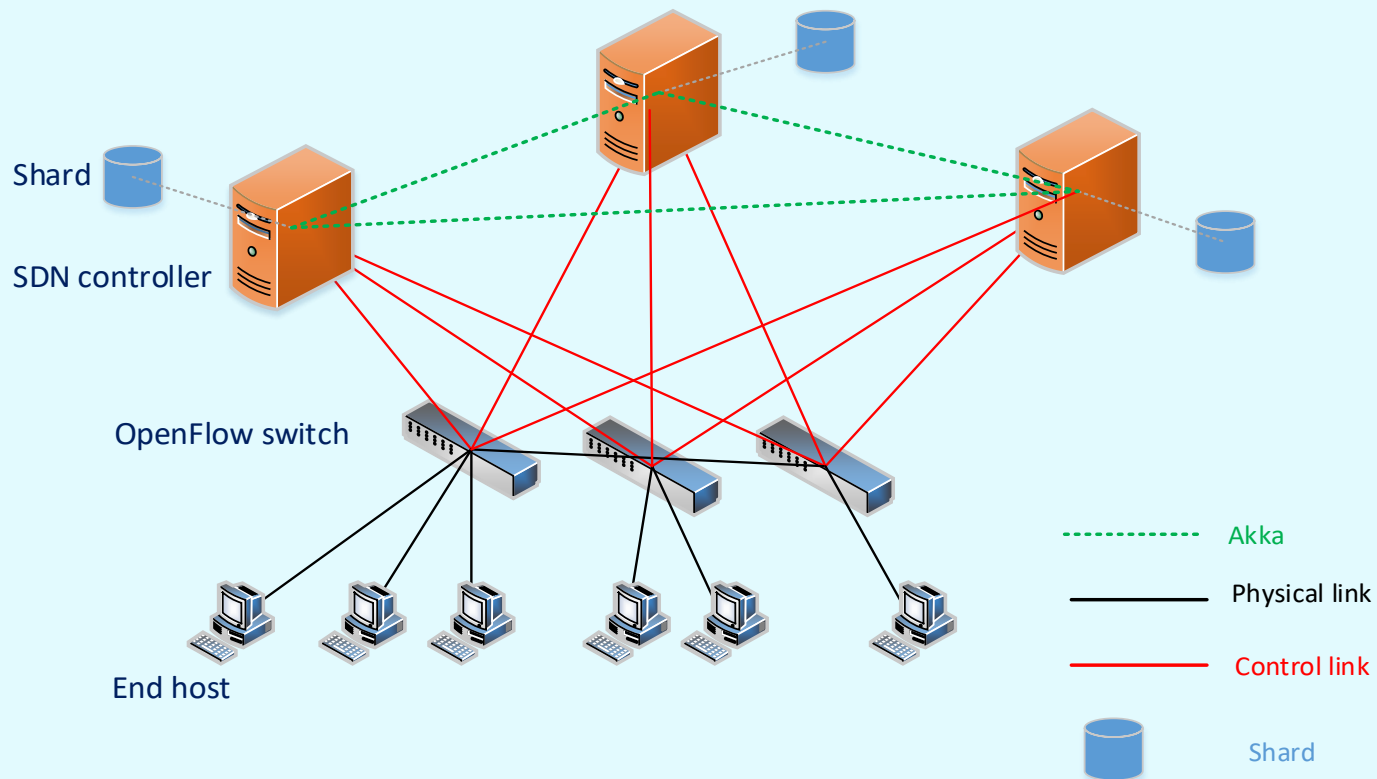
Important Research Results

- 1st year
 - **Multiple controllers synchronization** - proposed a **fast** Paxos-based consensus algorithm
 - **SDN security** – proposed a **northbound security enforcement interface** (NSEI) & an anomaly detection mechanism
- 2nd year
 - **Hierarchical SDN architecture** - proposed a hierarchical controller architecture & a **genetic algorithm-based** load balancing algorithm
 - **SDN security** - proposed a **recovery-enabled SDN** (ReSDN) architecture & a data plane state recovery mechanism

Recently Completed Project 1

SDN Multiple Controllers: Synchronization and Hierarchical SDN Architecture

SDN Multi-controller Architecture





A Fast Consensus Algorithm for Multiple Controllers

- In order to reach a consistent network state among multiple SDN controllers, we propose a fast Paxos-based consensus algorithm
- The proposed FPC provides a strong consistency and can guarantee that a proposal will be elected in each round and no additional round is needed even more than two proposers get the same votes
- The proposed FPC does not have the leader election issue (leader-free) and loads won't fall on a certain controller



Experiment Results

- Toaster REST API access time with 3-node ODL Clustering
 - We show that the **consensus time will affect the data store access performance**
 - The proposed FPC is **26.0%** faster at retrieving data and **59.7%** faster at storing data than Raft

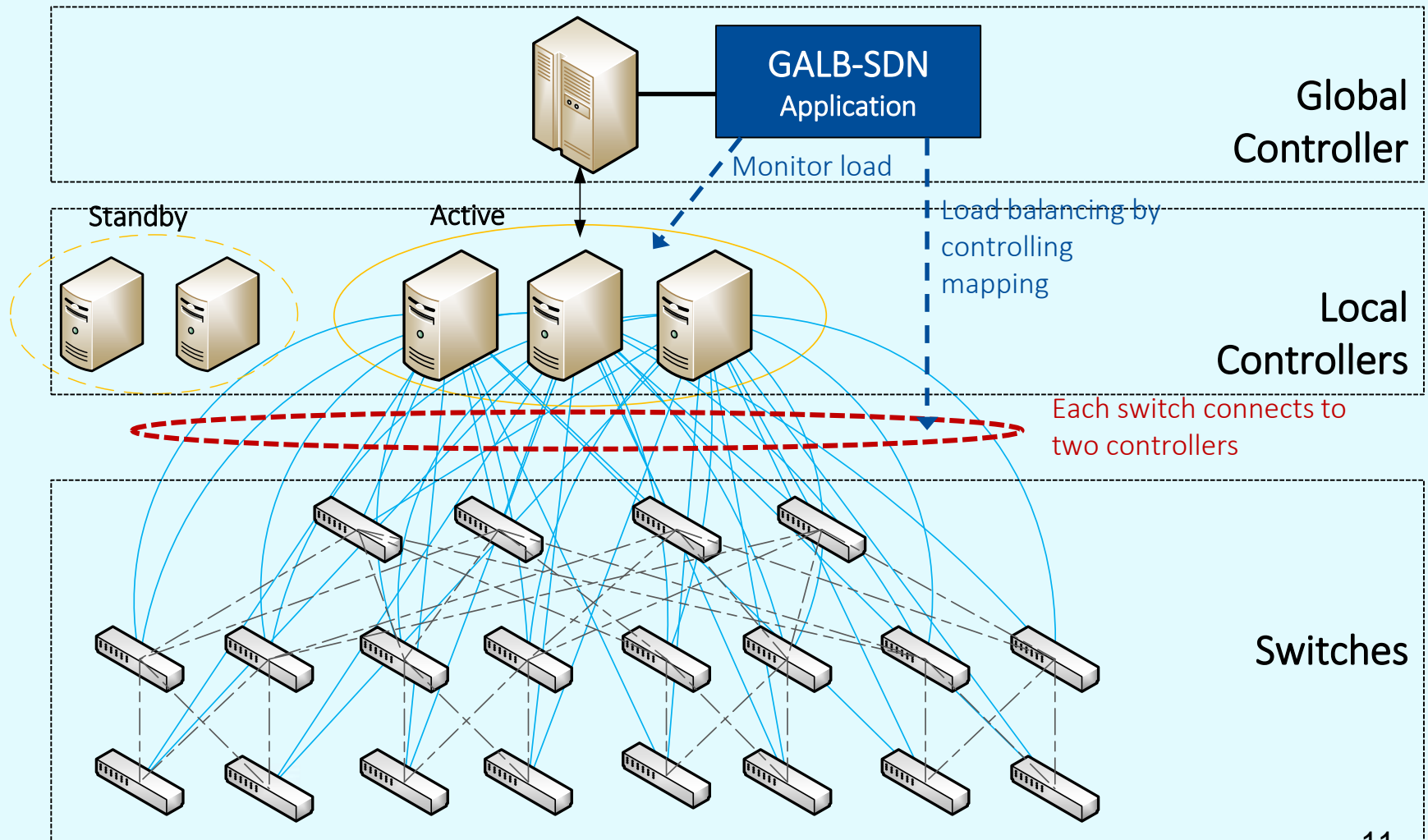
Request Consensus Algorithm	Retrieving Data	Storing Data
Raft, requests from Leader controller	5.415ms	11.691ms
Raft, requests from Follower controller	10.323ms	60.513ms
Raft (average)	8.687ms	44.239ms
FPC (proposed)	6.425ms	17.814ms



A Genetic Algorithm-based Load Balancing Mechanism

- We proposed a Genetic Algorithm based Load Balancing (GALB) mechanism to enhance the multiple controllers' performance and to reduce load balance time
- The proposed GALB introduces average deviation and migration latency to the genetic algorithm so as to achieve better load balancing and lower load balance time

Hierarchical SDN Multi-controller Architecture

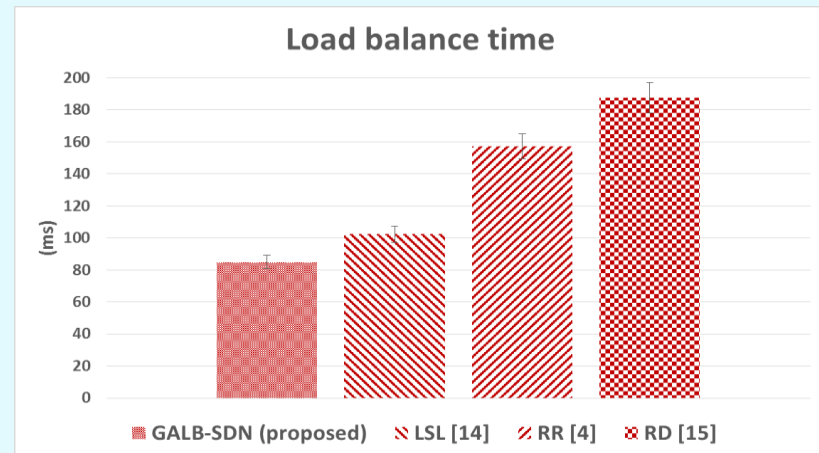
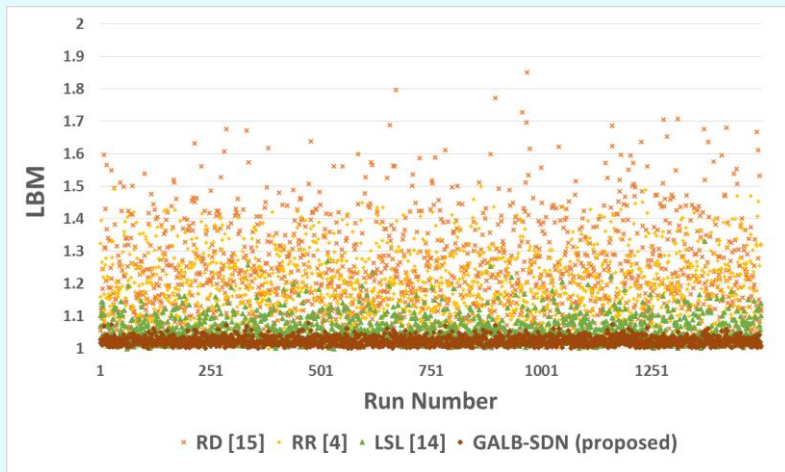


Experiment Results

- **LBM** (Load balance metric)
- **Load balance time**

Mechanism	RD	RR	LSL	GALB-SDN (proposed)
AVG LBM	1.24	1.19	1.06	1.02
Stander deviation	0.139	0.098	0.04	0.013
MAX disparity	0.802	0.478	0.307	--
MIN disparity	-0.016	-0.038	-0.061	--

Mechanism	GALB-SDN (proposed)	LSL	RR	RD
AVG run time (ms)	10.8	0.0017	0.0014	0.0012
AVG load balance time (ms)	84.72	102.24	157.22	187.42



Ongoing Project

Integrated Failure Detection and Failure Recovery Mechanism (思銳, 科技部)



Summary

- Integrate low mistake rate failure detection and genetic algorithm-based failure recovery mechanisms for SDN multiple controllers
- Build a testbed to evaluate the performance of failure detection and recovery mechanisms for SDN multiple controllers

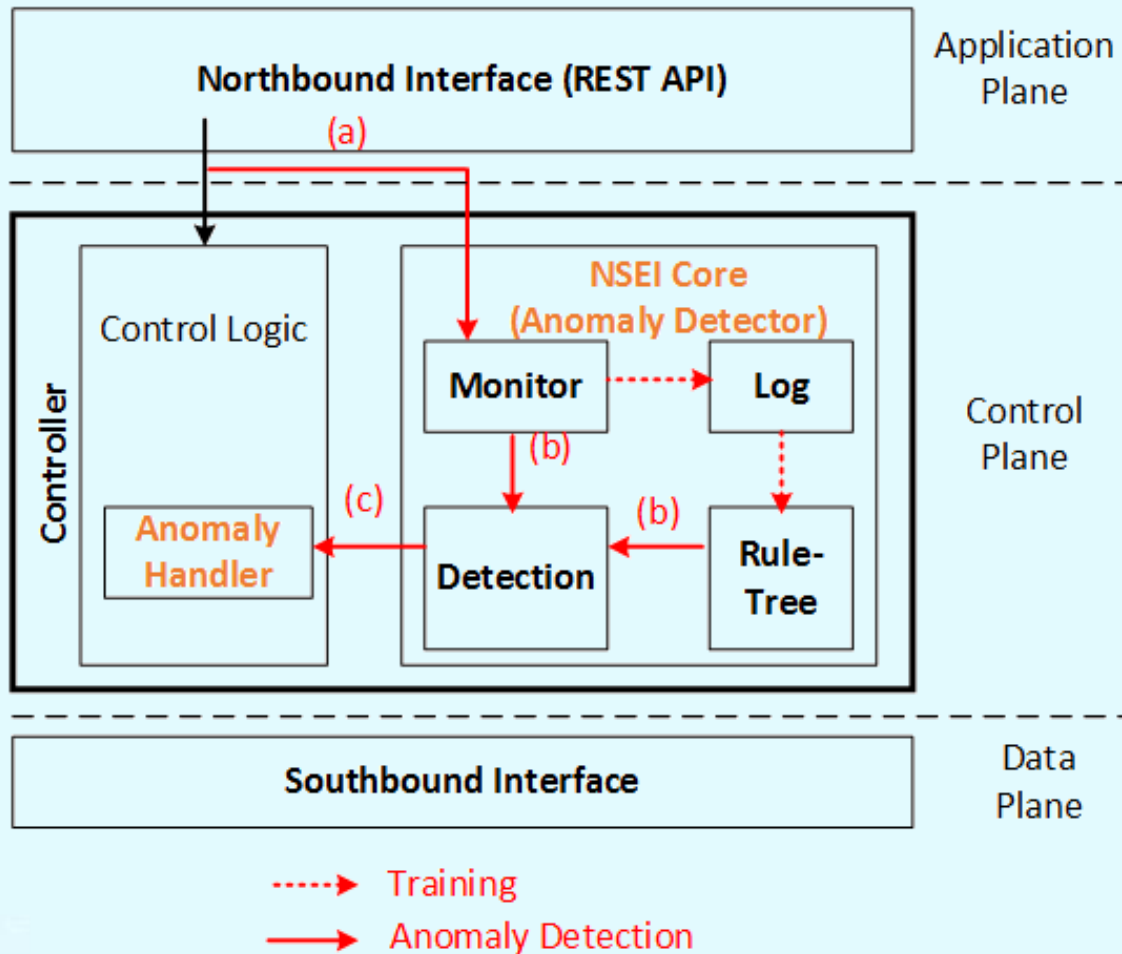
Recently Completed Project 2

SDN Multiple Controllers: Security Issues

Proposed NSEI for Anomaly Detection

- The SDN controller gives too much trust to SDN apps such that **malicious/buggy SDN apps** have opportunities to **attack** the SDN network
- The proposed **NSEI** adopts a **whitelist** to detect abnormal requests from each application
 - The whitelist of each application can be obtained by **behavior mining**, which trains a normal request data set, and is collected in white box testing

NSEI Architecture



Experiment Results

- **Anomaly detection accuracy**
 - Successful anomaly detection rate: **97.50%**

Prediction behavior	True positive rate	False negative rate
Routing	99.74%	0.26%
Host tracker	100%	0%
	False positive rate	True negative rate
Flood <i>GET</i> request	4.04%	95.96%
Flood <i>SET</i> request	1.60%	98.40%
Abnormal routing	18.80%	81.20%
Unexpected behavior	0%	100%

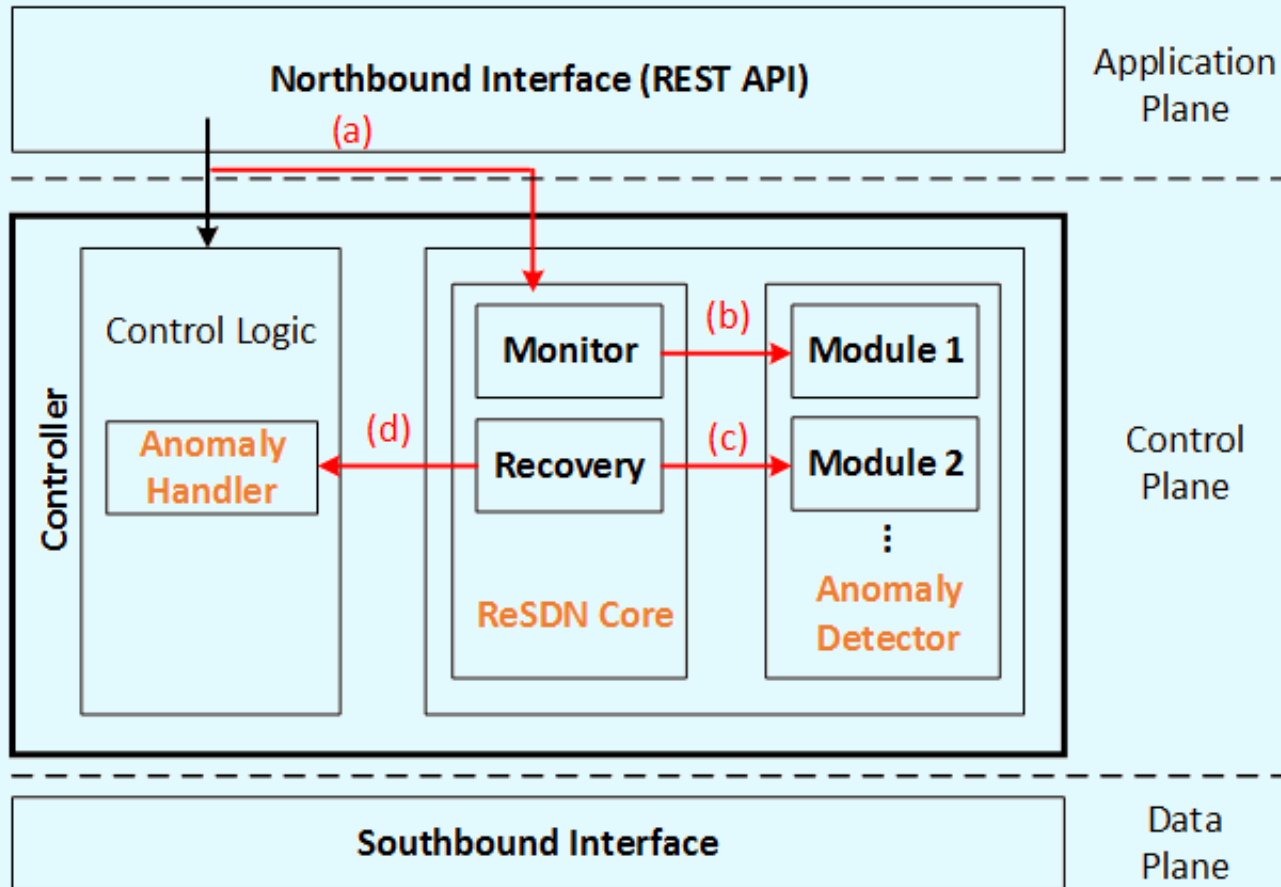


Proposed ReSDN for Anomaly Recovery

- Malicious/buggy SDN apps may have **contaminated the data plane state** even their anomalous operations were detected
- We proposed **ReSDN**, a **lightweight solution for data plane state recovery** in SDN
 - The proposed ReSDN monitors and logs all the network actions into a **flow table tree**, and then undoes the abnormal network actions once any recovery is needed

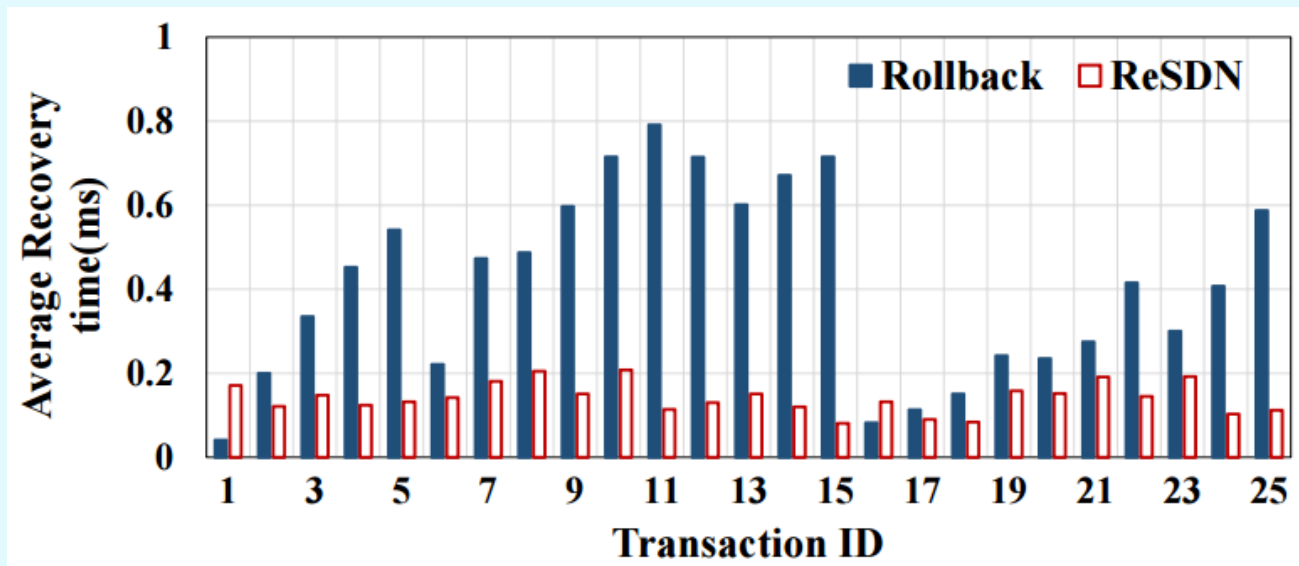


ReSDN Architecture



Experiment Results

- Proposed **ReSDN** and Rollback have the average recovery time, **0.14 ms** and **0.4 ms**, respectively
 - ReSDN requires only **34.1% of the time** needed by Rollback



Ongoing Project

Integrated Anomaly Detection and Anomaly Recovery (思銳, 科技部)

Summary

- **Integrate** NSEI (anomaly detection) and ReSDN (anomaly recovery) to realize a comprehensive northbound-security SDN architecture
- **Improve** the anomaly detection mechanism
 - NSEI only verifies if an incoming behavior occurred in the past, but **not its correctness**
 - **For correctness**, we determine **whether a transaction violates basic network behaviors** (e.g., loop-free, traffic reachability, etc.)

Recently Completed Projects

Flow Aggregation, Rule Caching and Replacement in SDN Networks (英業達, 科技部)

Important Research Results

- OpenFlow switch flow table is usually implemented by **TCAMs** for express forwarding
- TCAM is a **power hungry** and **expensive** hardware; therefore the size of switch flow table is limited that may result in the **flow table overflow problem**
- We proposed an **application-level dynamic flow aggregation algorithm** (1st year) and an **in-switch dynamic flow aggregation algorithm** (2nd year) to relieve the SDN flow table overflow problem

Recently Completed Project 1

Dynamic Flow Aggregation in SDNs for Application-aware Routing



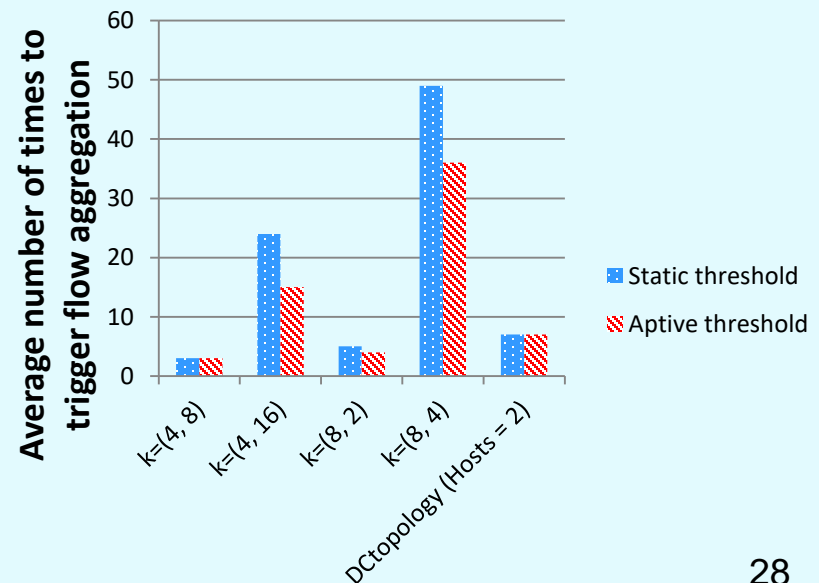
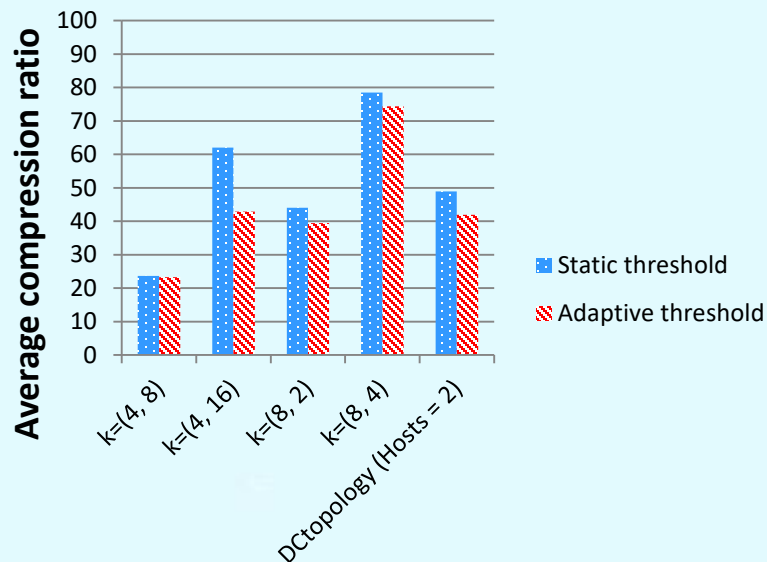
Proposed Bit & Subset Weaving

- We propose a novel **dynamic flow aggregation**, called **bit & subset weaving**, in SDNs for application-aware routing
- For rules in a switch, we produce **an instruction-independent partition** and then we apply **bit merging** or **subset merging** to each subset in a partition for flow aggregation
- We use **an adaptive threshold** according to the **average compression ratio** to achieve better flow aggregation



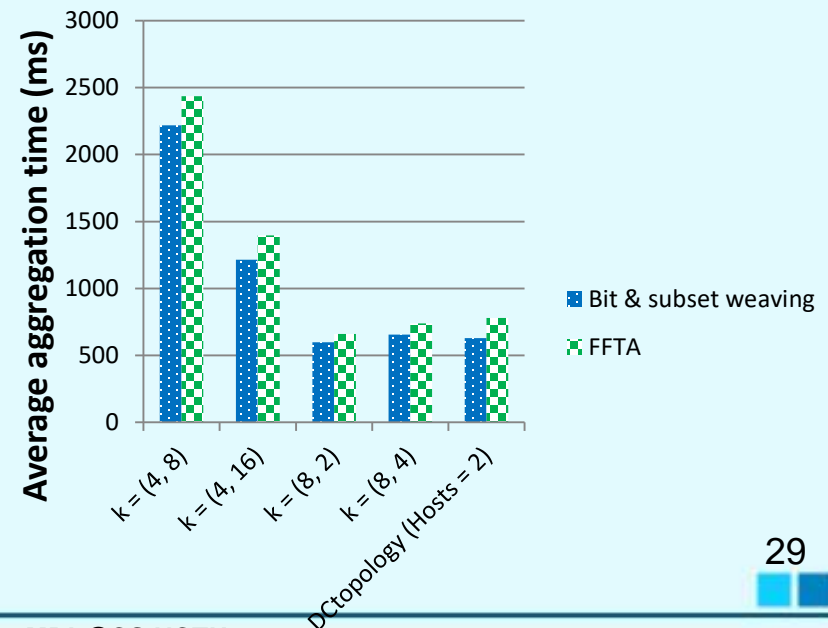
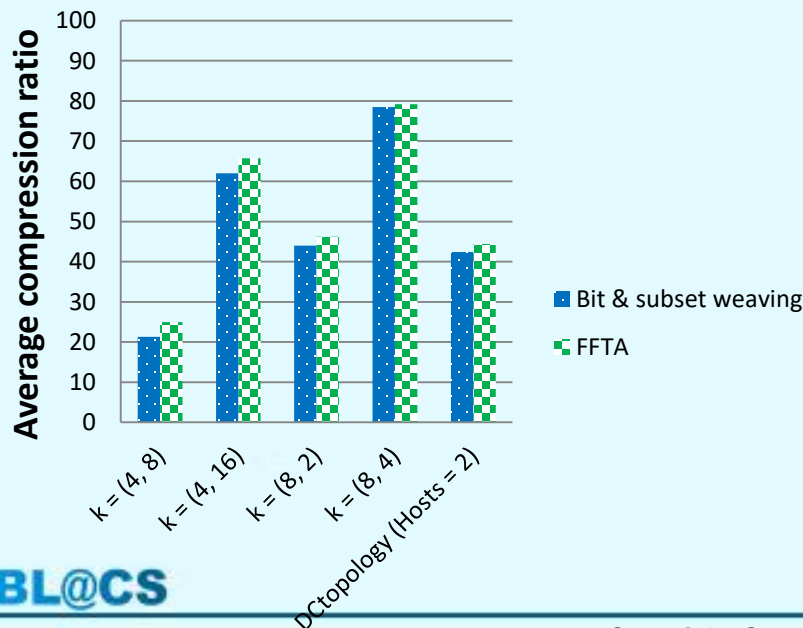
Experiment Results

- We evaluate the benefits of the proposed adaptive threshold in terms of average compression ratio for core layer switches and average number of times to trigger the flow aggregation



Experiment Results

- We evaluate the proposed bit & subset weaving and FFTA with static threshold in terms of average compression ratio and average aggregation time
- The average compression ratio of the proposed algorithm is 2.05% better than that of the FFTA; the average flow aggregation time is 12% better than that of the FFTA



Recently Completed Project 2

In-Switch Dynamic Flow Aggregation in Software Defined Networks

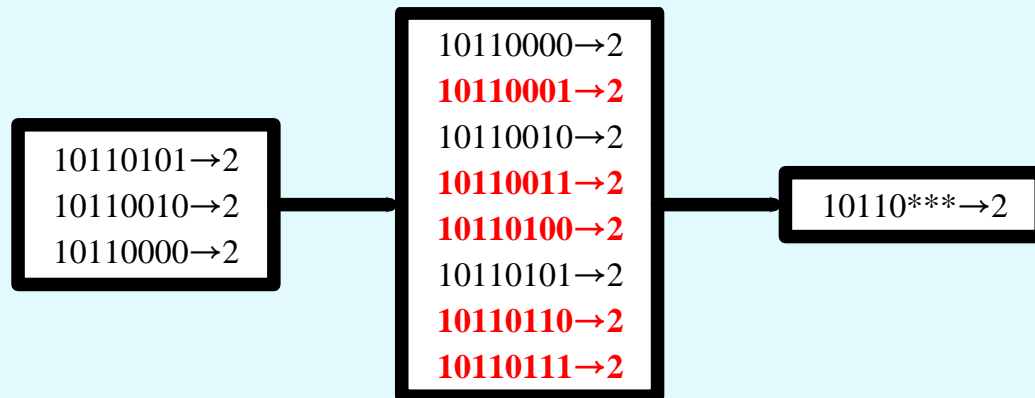


Overview

- We proposed a fast and efficient **In-switch Dynamic Flow Aggregation (IDFA) algorithm** to relieve the flow table overflow problem
- The IDFA has **shorter flow aggregation convergence time** and **lower flow table overflow probability**

Proposed IDFA Algorithm

- **Flow aggregation** with proactively inserting **redundant flow entries** to **speed up** the flow aggregation convergence time
- **Dynamic threshold** to make IDFA algorithm run **fewer times** when the flow table starts to **converge**



Flow entries
inside a switch

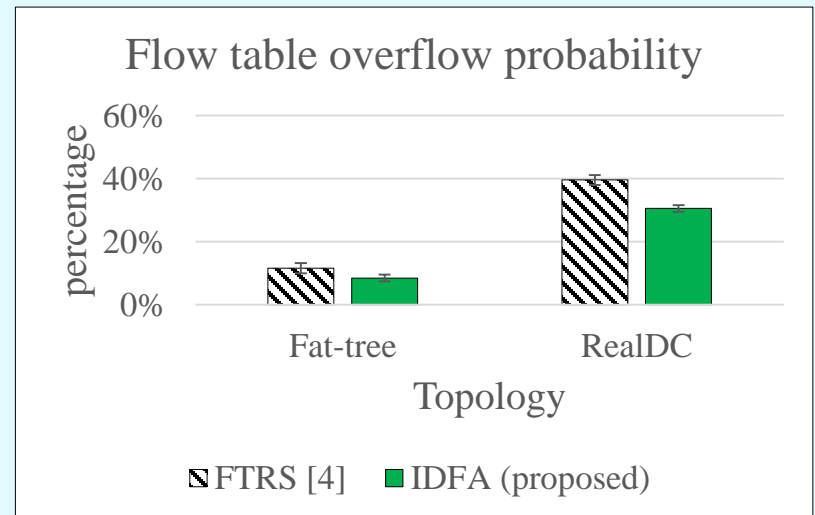
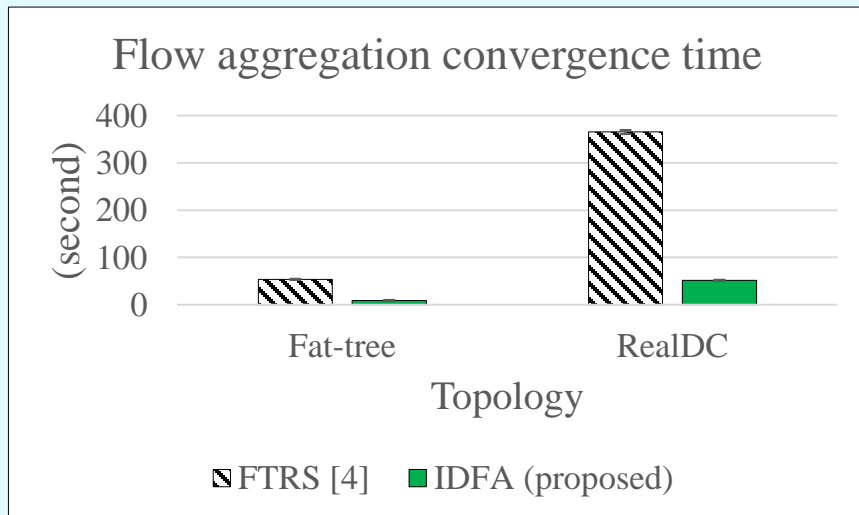
Add 5 more flow entries to
form a complete bit set

Flow aggregation
result

An example flow aggregation with redundant flow entries

Experiment Results

- The **average flow aggregation convergence time** of the IDFA in the fat-tree and the RealDC topologies are 84% and 85.9%, respectively, shorter than that of the FTRS
- The **flow table overflow probability** of IDFA in **fat-tree** and the **RealDC** topologies are **26.71%** and **22.83%**, respectively, lower than that of the FTRS



Ongoing Project

In-switch Rule Caching and Replacement Algorithm (英業達, 科技部)

Summary

- We are working on an **in-switch rule caching and replacement algorithm**
- We will perform flow logging to model the characteristic of each flow in terms of **inter-arrival time distribution**
- We will derive the **incoming flow matching probability** for each rule **including aggregated rules** based on the inter-arrival time distribution of each single flow
- Flow entries **with low probability** will be replaced proactively to improve the **hit rate** of TCAM

Recently Completed Projects

Software Defined Networking in High Performance Big Data Analysis System (科技部)



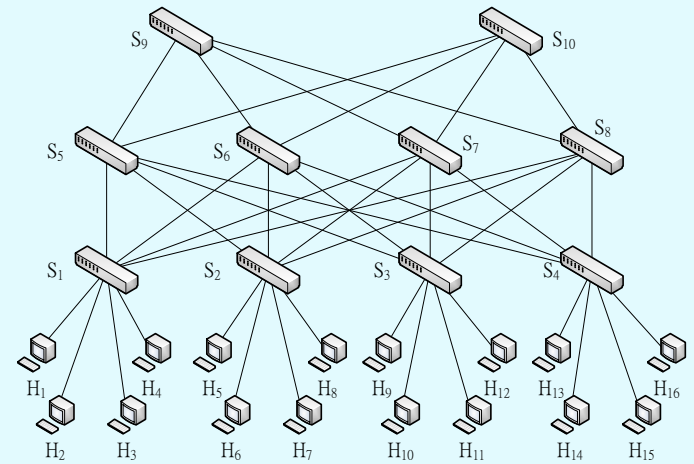
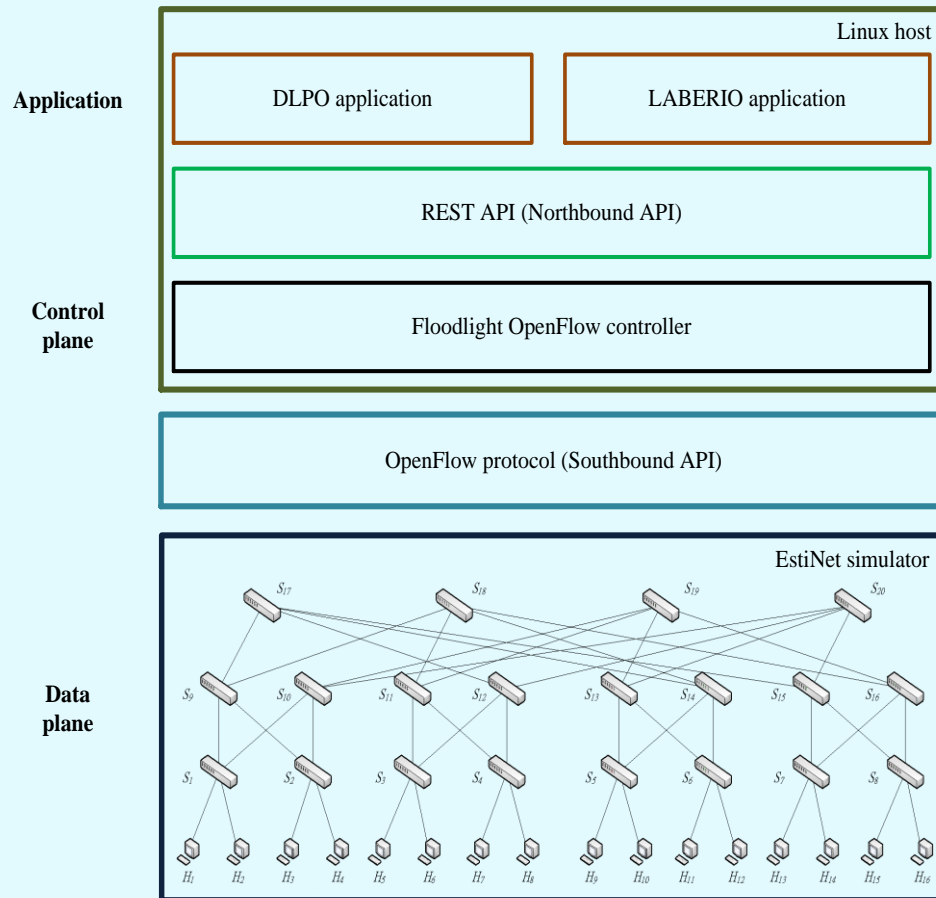
Important Research Results

- **1st year:** proposed a **dynamic load-balanced path optimization** mechanism in SDN-based data center networks
- **2nd year:** proposed a **QoS-aware ellipse equation based routing** algorithm for SDN-based data center networks
- **3rd year:** proposed a **simulated annealing based QoS-aware routing** algorithm in **SDN hybrid networks**

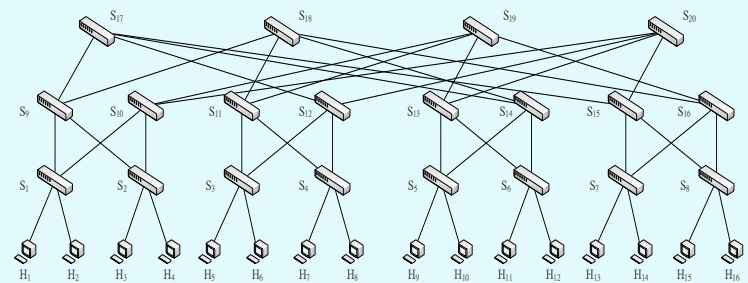
Dynamic Load-balanced Path Optimization

- With more and more data transmitted in data center networks, the traffic exchanged among switches in data center networks has grown up rapidly, which may lead to the **congestion problem**
- We propose a **Dynamic Load-balanced Path Optimization (DLPO)** algorithm
 - Is **suited for different SDN-based data center network topologies**
 - May change paths of flows during flow transmissions
 - Achieves **load balancing among different links**
 - Efficiently **resolves the network congestion problem**

Evaluation Architecture and Topologies



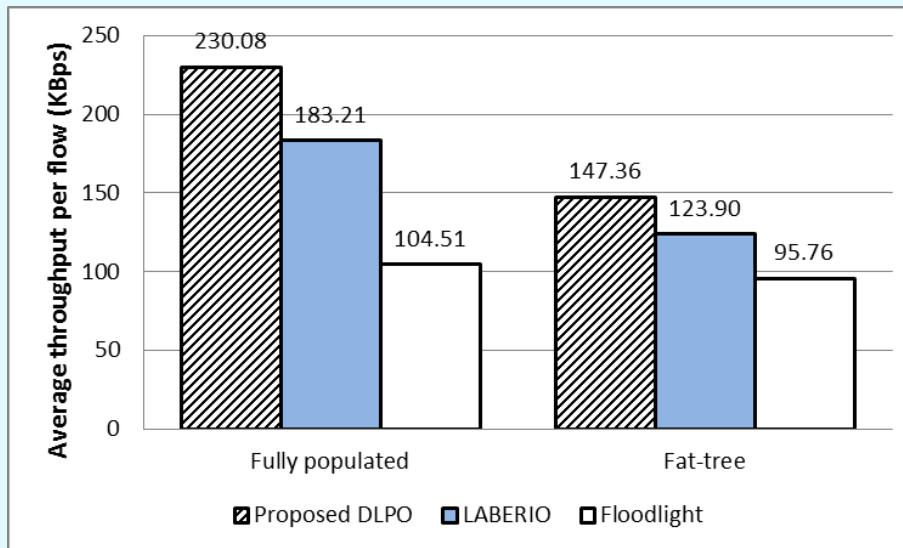
Fully populated topology



Fat-tree topology (with $k = 4$)

Experiment Results

- In a fully populated topology
 - DLPO increases **24.8%** and **120.2%** of **throughput** compared to LABERIO and Floodlight, respectively
- In a fat-tree topology
 - DLPO increases **18.9%** and **53.8%** of **throughput** compared to LABERIO and Floodlight, respectively





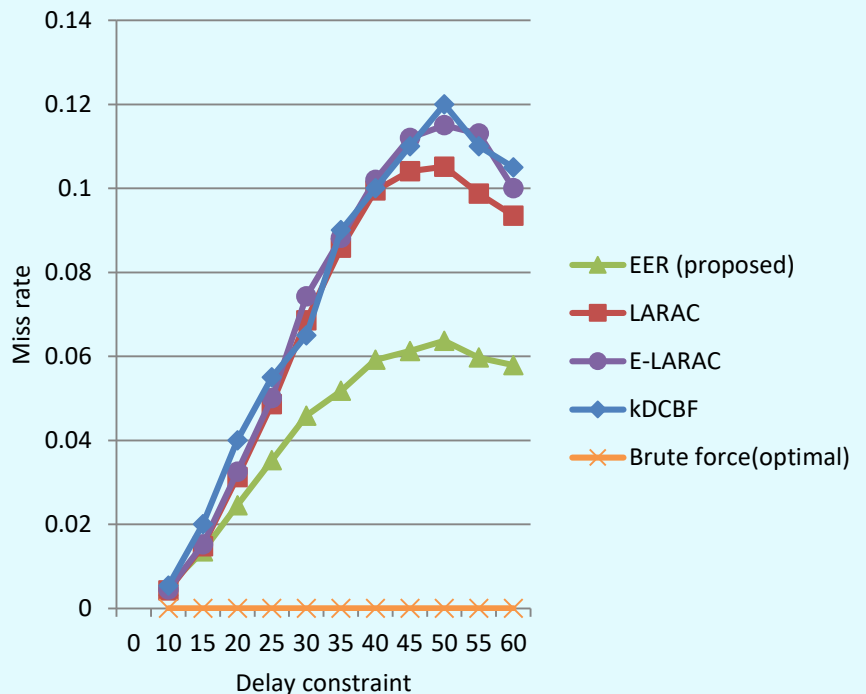
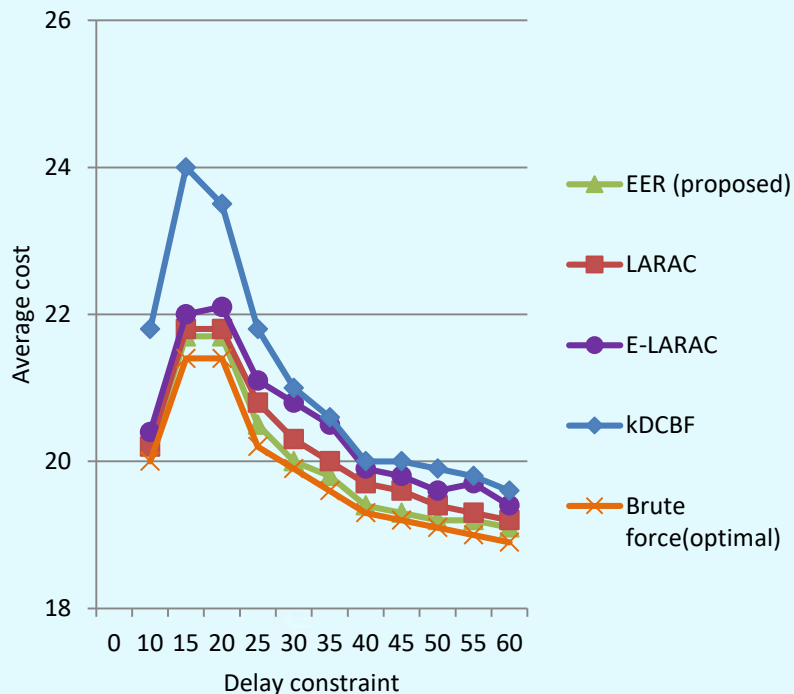
An Ellipse based QoS-aware Routing Algorithm

- With more and more data transmitted in data center networks, **QoS (e.g., delay) requirements** of applications need to be paid attention
- The proposed **Ellipse Equation based Routing (EER)** algorithm leverages the **Lagrangian Relaxation** method and an **ellipse equation** to find an approximate optimal path, which can satisfy the QoS requirements and **the path is closer to the optimum path**
- The proposed EER can **find the least cost path whose delay is bounded by delay constraint in polynomial time**



Experiment Results

- The proposed EER decrease **2.4%** of **average cost** (in terms of link utilization) compared to LARAC
- The proposed EER decrease **35.5%** of **miss rate** compared to LARAC



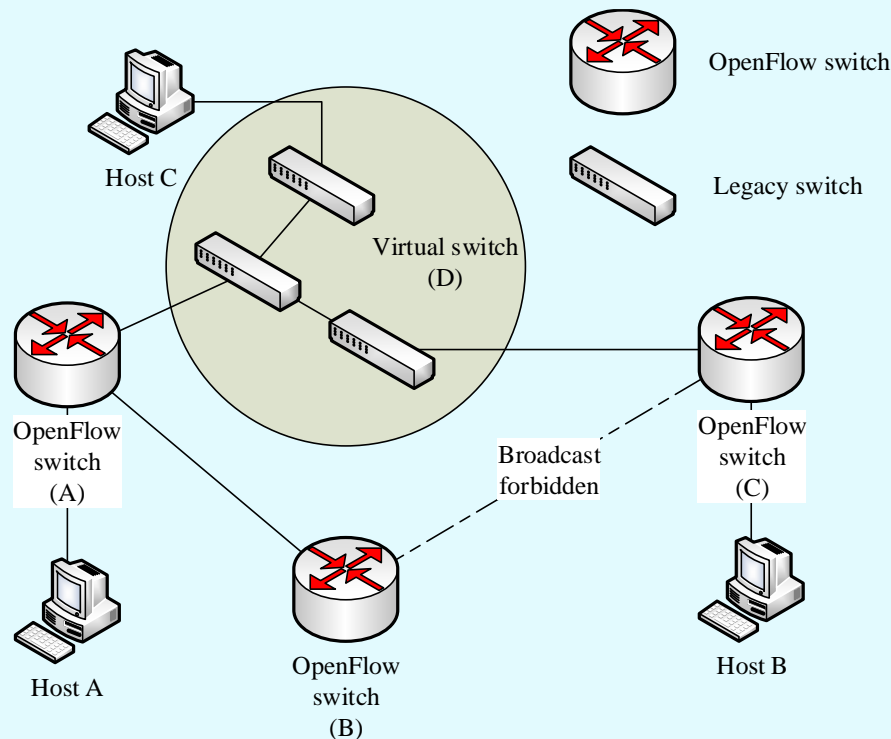


A Simulated Annealing based QoS-aware Routing

- The traditional data center network usually uses L2 switches because it has low CapEx/OpEx and easy to use (plug and play)
- But the **L2 switches are static** and thus **can't meet the QoS requirements** of different applications
- We **propose an SDN hybrid network architecture** which can let SDN applications do elastic routing by applying **discovering and controlling mechanisms** to legacy switches

SDN Hybrid Network Discovery

- **Host discovery:** by ARP packets
- **Broadcast storm:** build a spanning tree to forbidden broadcast storm
- **Controlling a legacy switch to send packets to the OpenFlow switch:** by the characteristic of MAC address learning in the Learning Bridge Protocol (LBP)

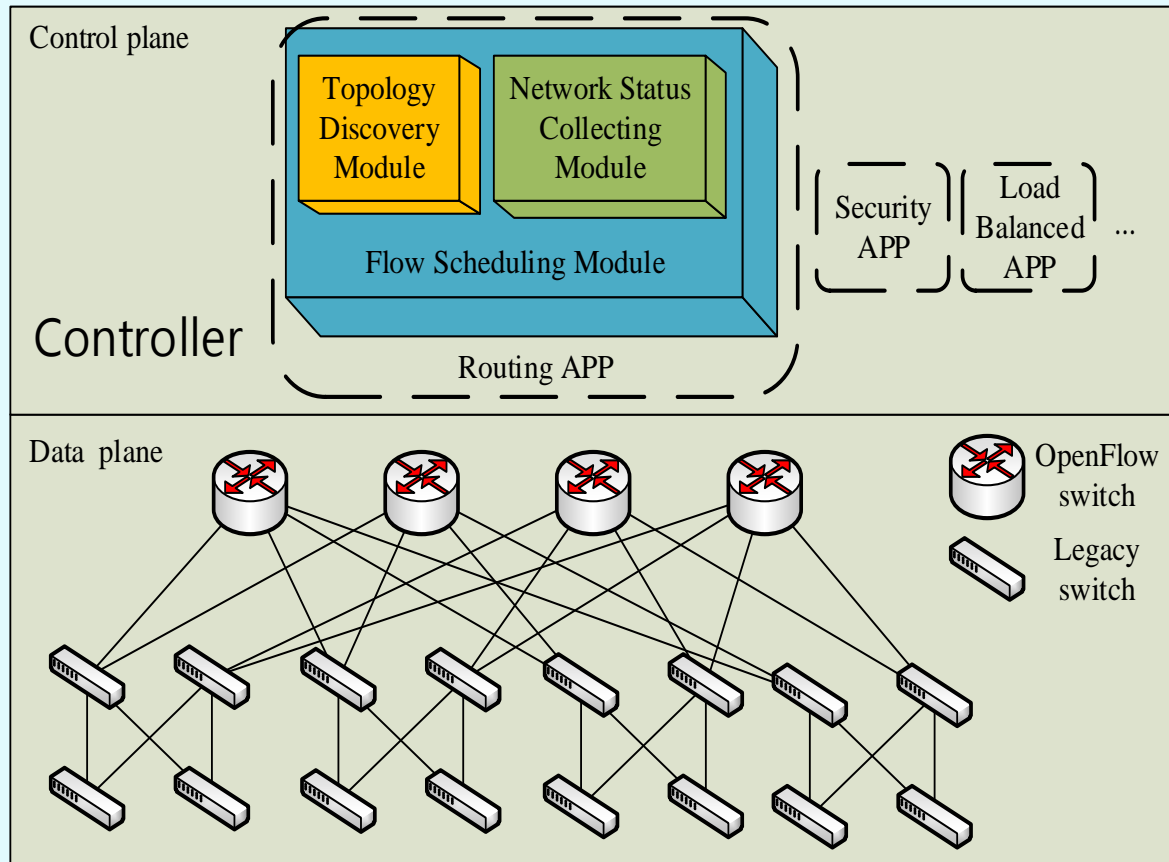




SDN Simulated Annealing based QoS-aware Routing

- We proposed a simulated annealing based QoS-aware routing (SAQR) algorithm which can adaptively adjust weights of delay, loss rate and bandwidth requirements in a cost function to find the best fit path to meet different QoS requirements

Evaluation Architecture

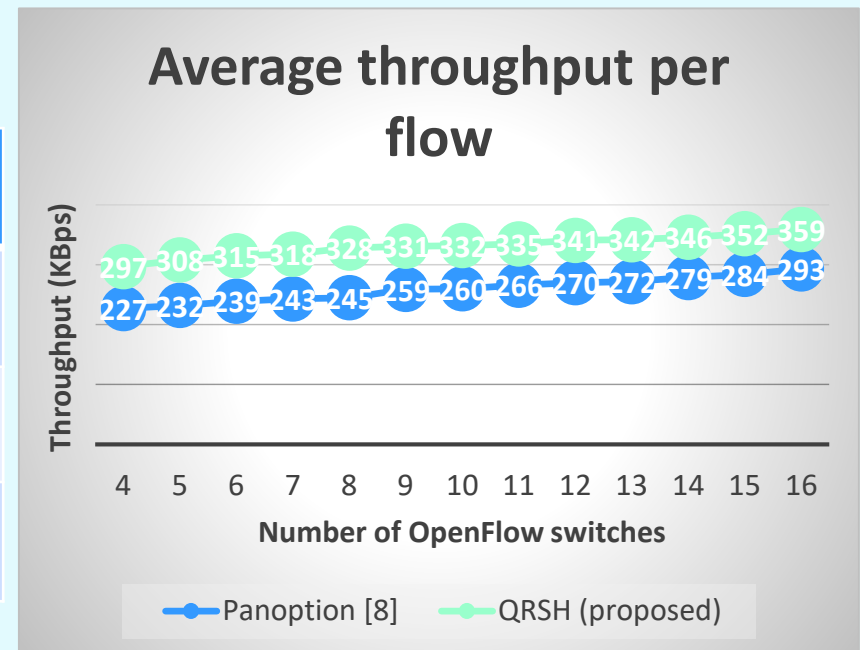


Experiment Results

- The proposed SAQR algorithm outperforms Mina in terms of **delay**, **loss rate** and **bandwidth** with at least 86% (63% for Mina) of **flows** meeting their **QoS requirements**

Method	Delay	Loss rate	Bandwidth
Dijkstra [13]	0.5	0.729	0.86
Mina [14]	0.625	0.824	0.875
QRSH (proposed)	0.88	0.908	0.865

- The proposed QRSH enhances **average throughput per flow** under a different number of OpenFlow switches deployed compared to Panoption



Ongoing Project

Software Defined IoT Networking with 3i (科技部)

Summary

- **Software Defined IoT Networking with 3i**
 - **Integration**: The proposed SD-IoT+3i **integrates heterogeneous networks** so as to meet the QoS requirements of different IoT devices
 - **Intelligence**: The proposed SD-IoT+3i achieves IoT devices **location-awareness** via SDN controllers so as to achieve mobile IoT devices **seamless handover** and **load balancing** between IoT gateways
 - **Interoperability**: The proposed SD-IoT+3i enhances interoperability so that IoT devices can communicate through various networks (e.g., LTE-A or WiFi) and can attain **load balancing between different networks**

Existing Projects

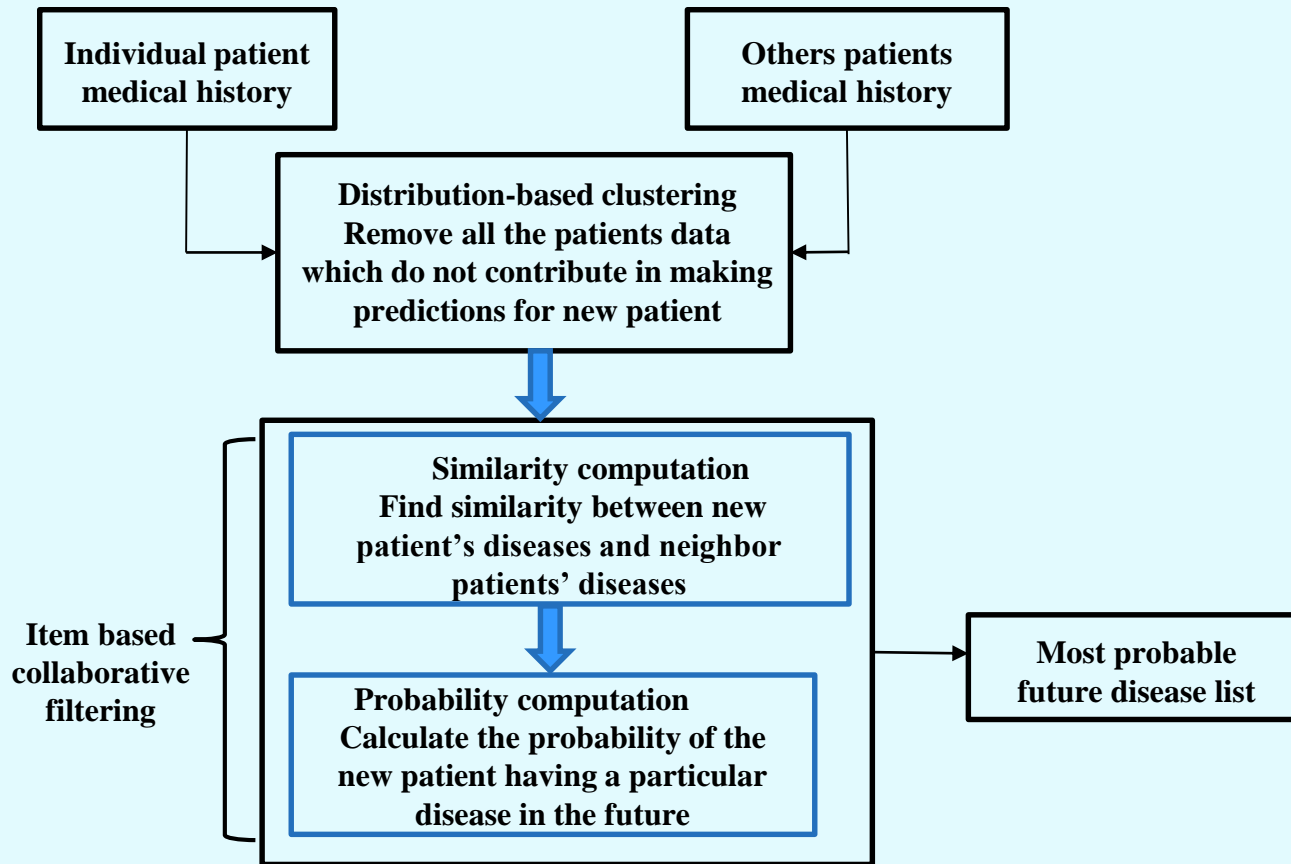
Big Data Analytics



Disease Risk Prediction

- We propose an **effective disease risk prediction system (EDRP)** to predict the diseases of a new patient
- EDRP integrates **distribution-based clustering** with **item-based collaborative filtering (CF)** to achieve better coverage and accuracy

EDRP System Architecture



Experiment Results

- The proposed EDRP is better than CFAIC and CARE in terms of **coverage** and **accuracy**

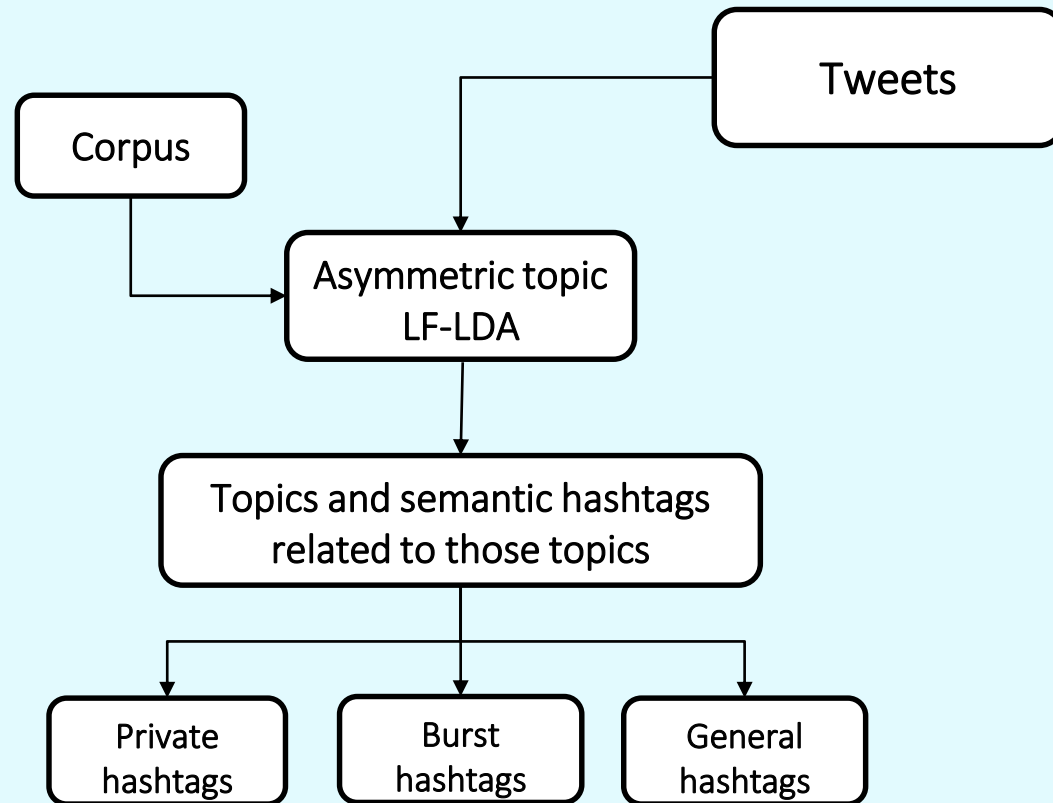
Approach	CFAIC	Care	EDRP (proposed)
(for top 20 predictions) Coverage Half-life accuracy	20.12% 28.67%	30.23% 31.25%	48.53% 38.3%
(for top 100 prediction) Coverage Half-life accuracy	56.75% 65.80%	71.39% 82.11%	79.12% 87.86%
(for all prediction) Coverage Half-life accuracy	67.08% 78.12%	86.58% 89.42%	94.08% 98.23%



Topic Derivation in Twitter

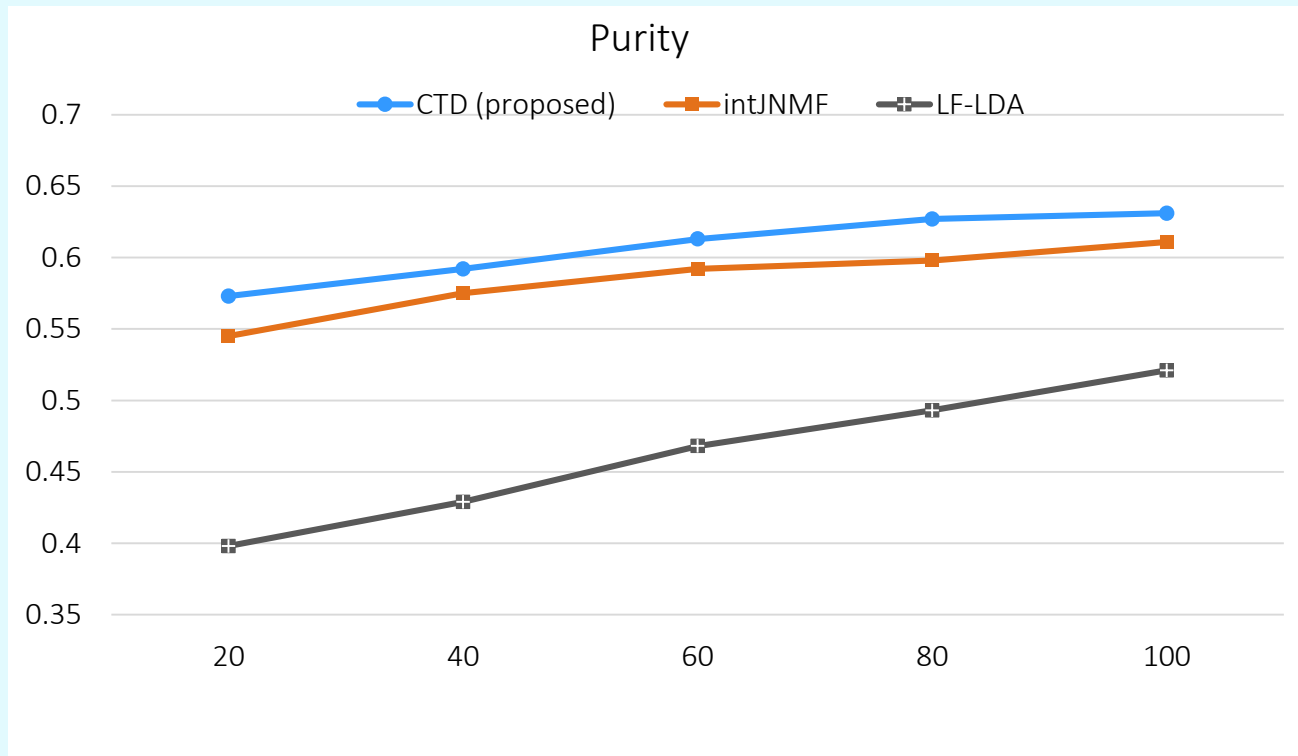
- Due to short (140 characters) nature of tweets it is **difficult to derive topics with good purity** and related works on topic derivation in Twitter lack purity
- We propose a **corpus-based approach** to identify topics and clusters of similar hashtags using corpus with LF-LDA so as to increase the purity of the resulting topics

Corpus-based Topic Derivation (CTD) Architecture



Experiment Results

- **Purity** for different number of topics

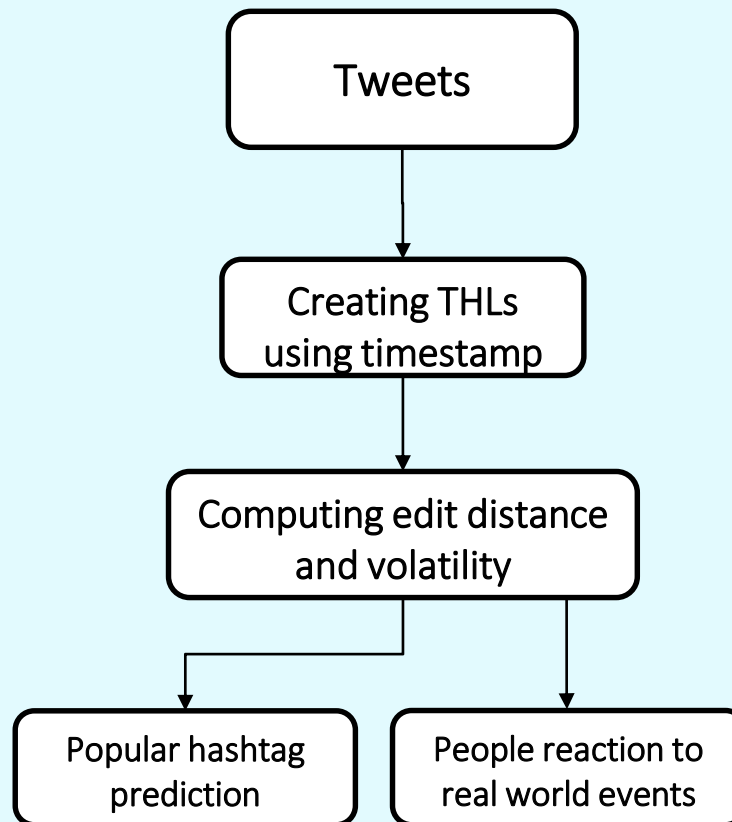




Timestamp-based Popular Hashtag Prediction

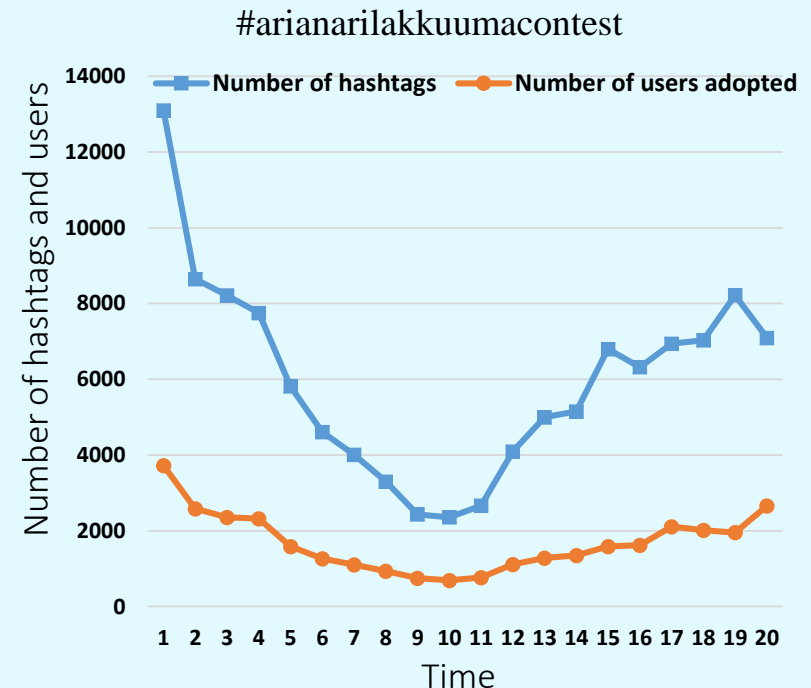
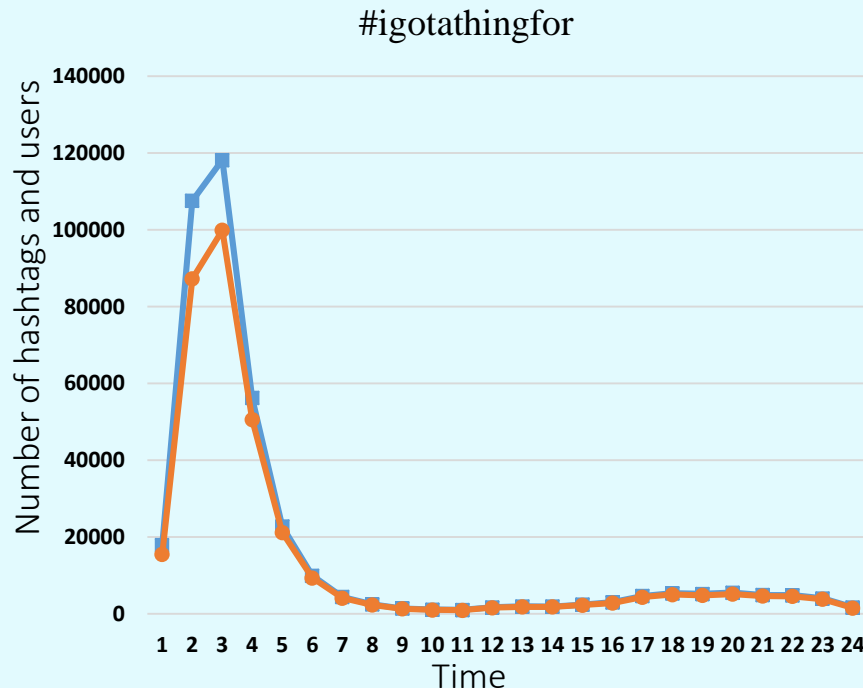
- Popular hashtag prediction with **better precision** in social media like Twitter is hard to achieve
- Hence we propose **timestamp-based popular hashtag prediction** (TPHP) approach to predict popular hashtags and **to improve precision**

Proposed TPHP Architecture



Experiment Results

- Difference between two **trending hashtags** with respect to number of users adopted



Top trending hashtags on Jan-14-2013 and Jan-24-2013. Comparison between total number of hashtags used and number of users adopted (used) that hashtag

Ongoing Project

Broker-based Portfolio Selection in Stock Market

Summary

- In portfolio selection, we study how to **allocate an investor's wealth among a basket of stocks** to achieve a tradeoff between return and risk
- In contrast to previous works, we apply **stock transaction historical data of each broker**, not the mean and deviation of a stock's price to predict the market trend



Ongoing Project

Integrated WiGig/WiFi Networking
(產學大聯盟, 科技部)

(With Prof. ChiYu Lee)





Summary

- **WiGig**, operating in 60 GHz, allows devices to communicate without wires at **multi-gigabit speeds**
- **Integrate WiGig/WiFi networks for smart campus applications**, such as VR HMD (virtual reality head-mounted display) and online virtual classrooms
 - **Handover between WiGig and WiFi**
 - **Use WiFi for control signaling**





Thank You