TinyEdge: Enabling Rapid Edge System Customization for IoT Applications

Wenzhao Zhang, Yuxuan Zhang, Hongchang Fan,
Yi Gao, Wei Dong, Jinfeng Wang

Zhejiang University

Alibaba-Zhejiang University Joint Institute of Frontier Technologies

Edge Systems and Applications are Increasing

Application

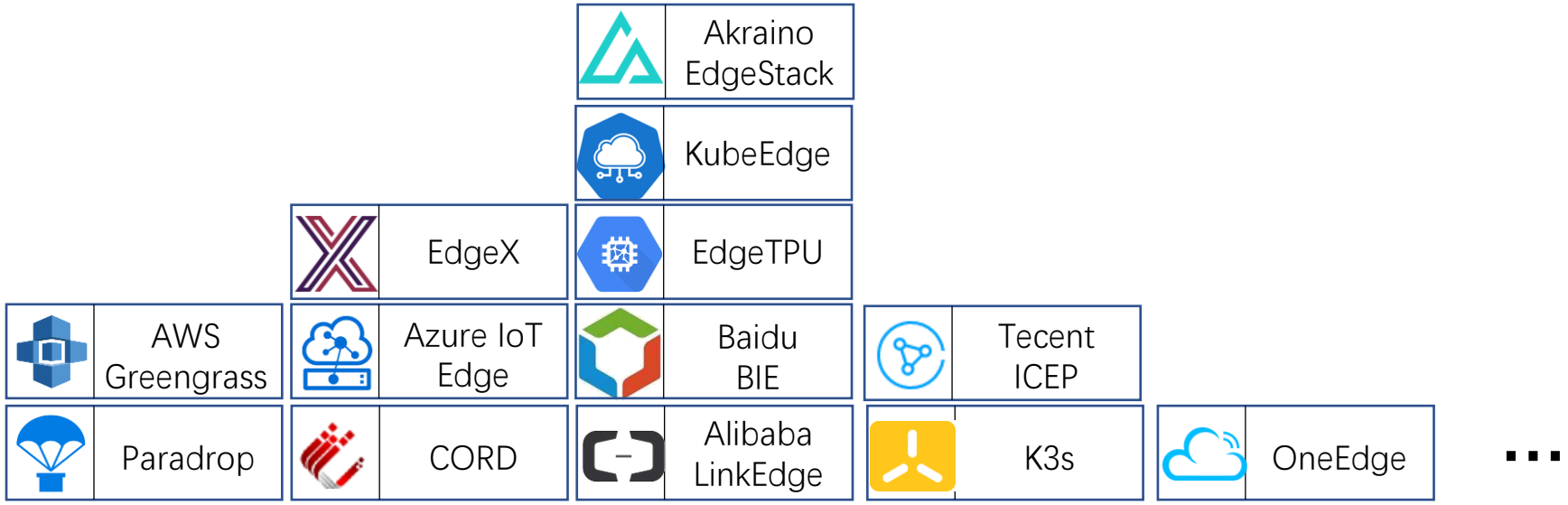
AR/VR

Video Surveillance

Autonomous Vehicle

...

System



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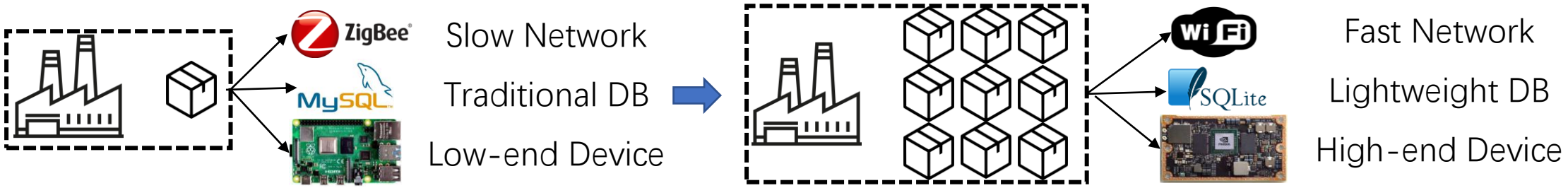
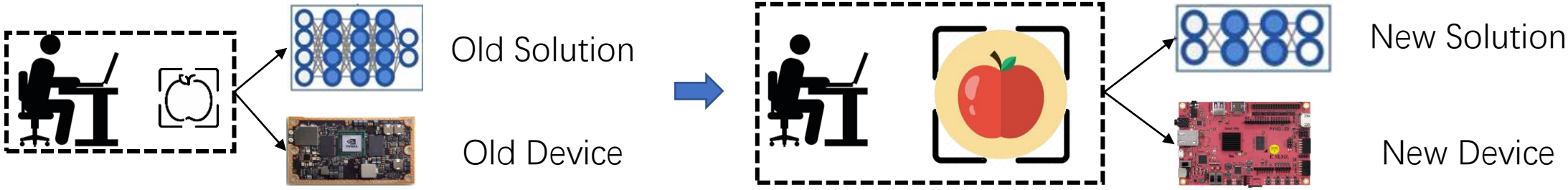
Why Do We Need Rapid Customization?

- **Similar Functionalities with Different Requirements!**
  - Scenario 1: Industrial Internet

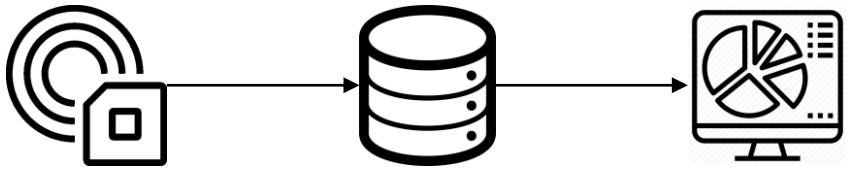


  - Scenario 2: Education Experiment



Conventional Customization Steps

- **Target Edge System**



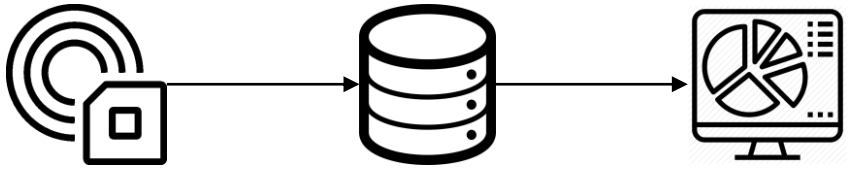
IoT Sensor Data Base Visualization

Option 1: Develop from the ground up

Option 2: Redevelop from existing modules

Conventional Customization Steps

- **Target Edge System**



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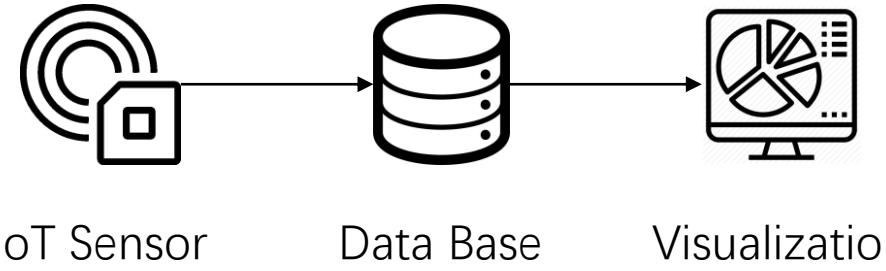

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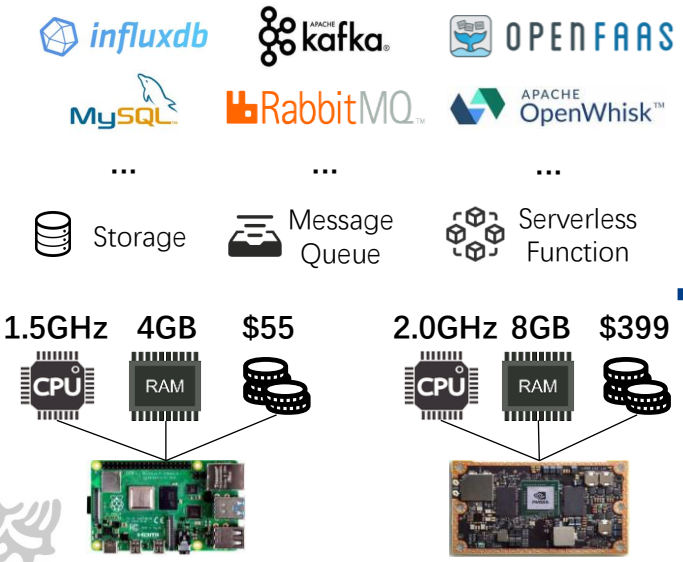
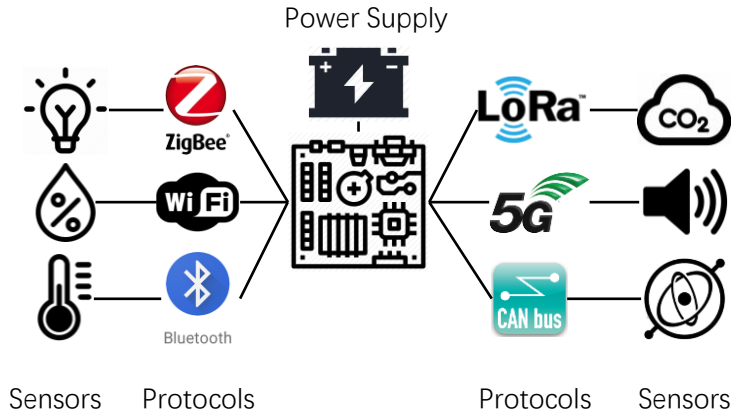


Prototype Design



System Integration

APP Development

Conventional Customization Steps

- **Target Edge System**

IoT Sensor Data Base Visualization

Option 1: Develop from the ground up ✗

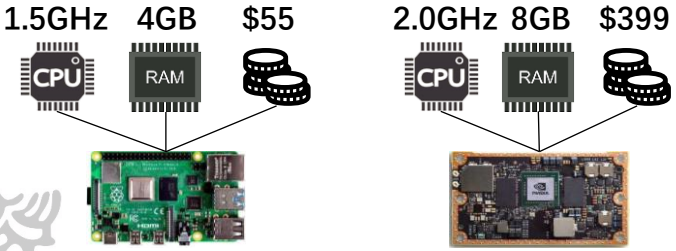
Option 2: Redevelop from existing modules

influxdb kafka OPENFAAS MySQL RabbitMQ APACHE OpenWhisk™

... ...

Storage Message Queue Serverless Function

1.5GHz 4GB $55 2.0GHz 8GB $399



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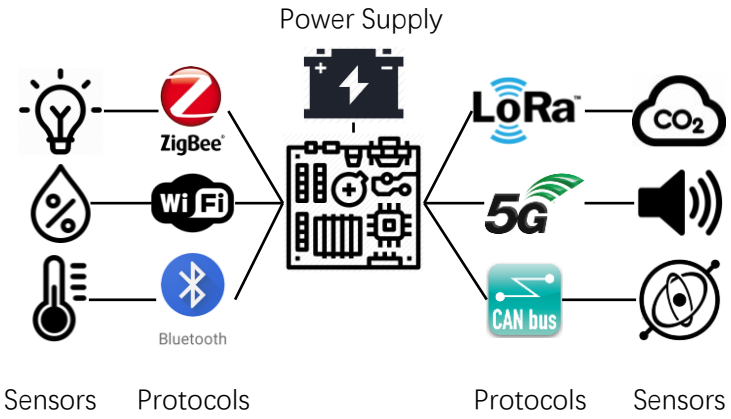
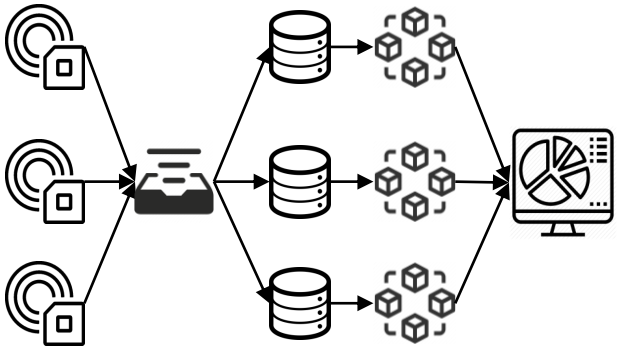


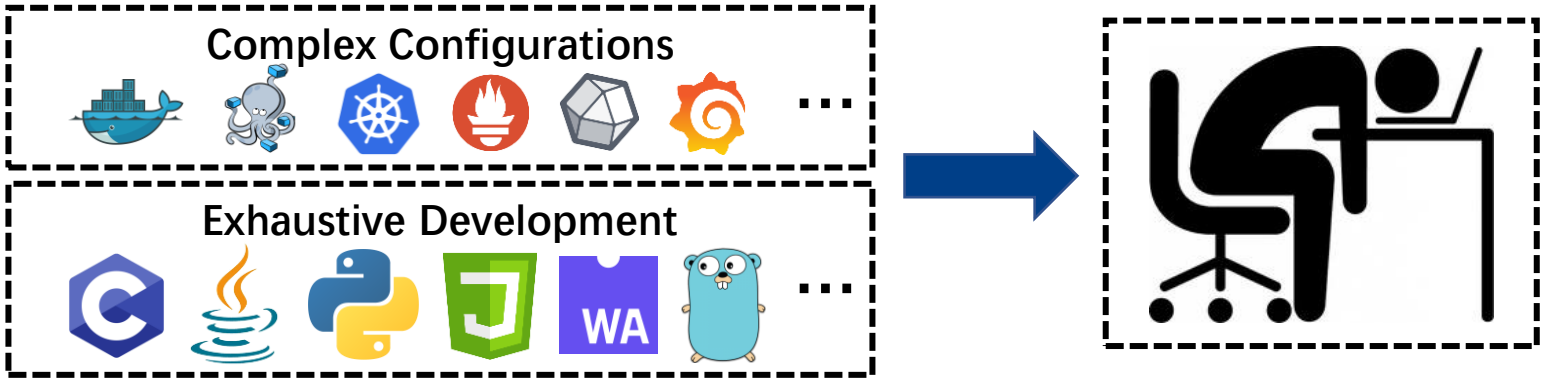
System Integration



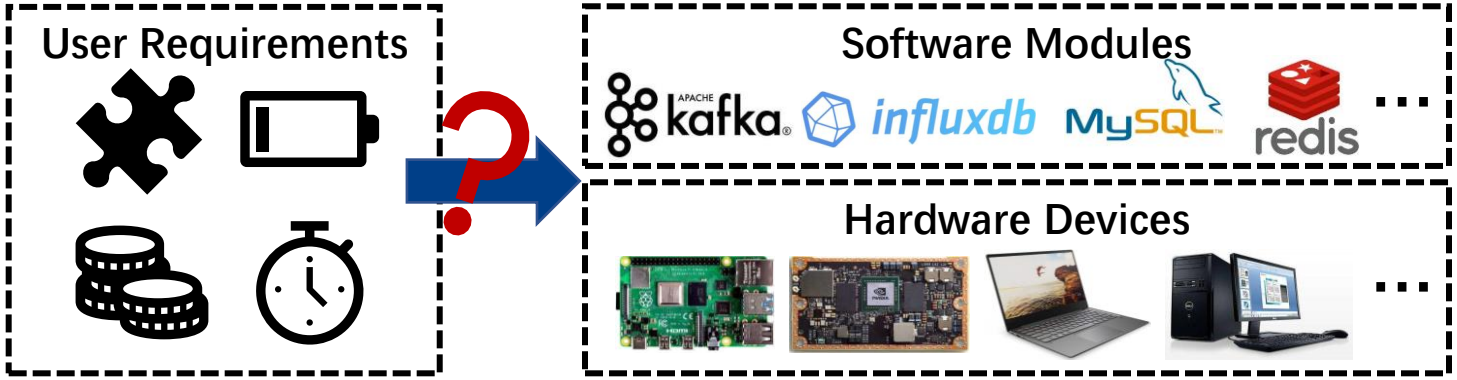
APP Development

Issues of Existing Work

- **Rapid Customization is HARD!**
  - Hard to redevelop from existing modules

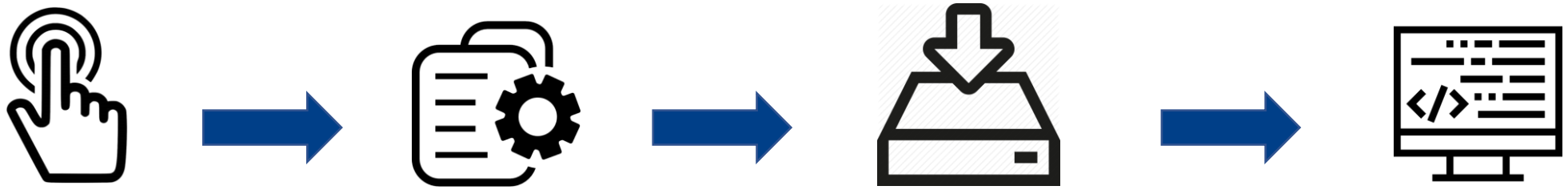


  - Hard to select hardware and software with better trade-off



TinyEdge Vision

- **Easy Customization**
  - Composing an edge system with simple steps



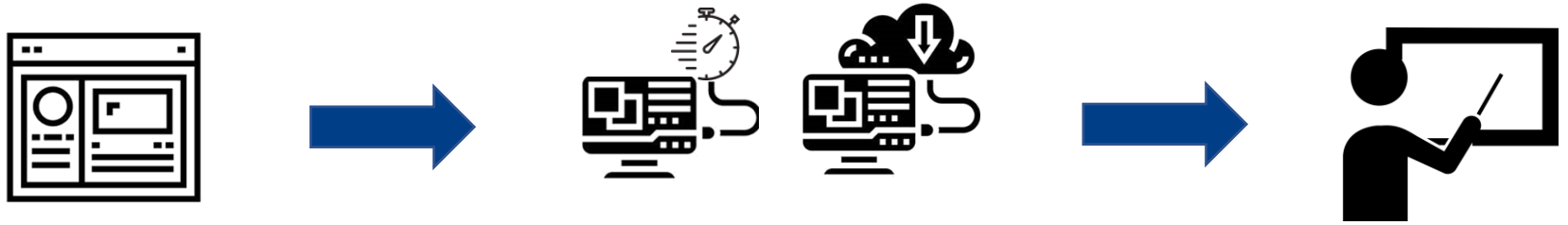
Click to select software modules

Provide high-level configuration

Use out-of-the-box deployment tool to set up

Write few lines of code to specify application logic

  - Being aware of system performance before deployment



Profile module condition under different situations

Latency Models

Workload Models

Hardware and software selection guidance

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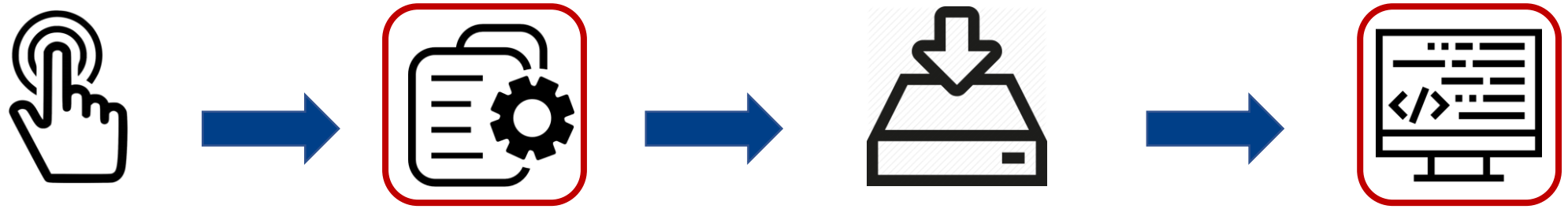

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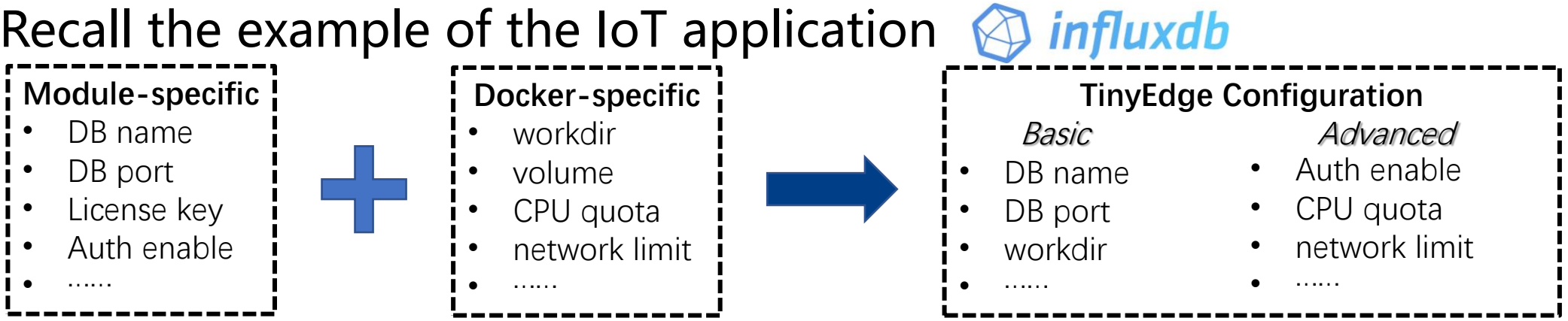
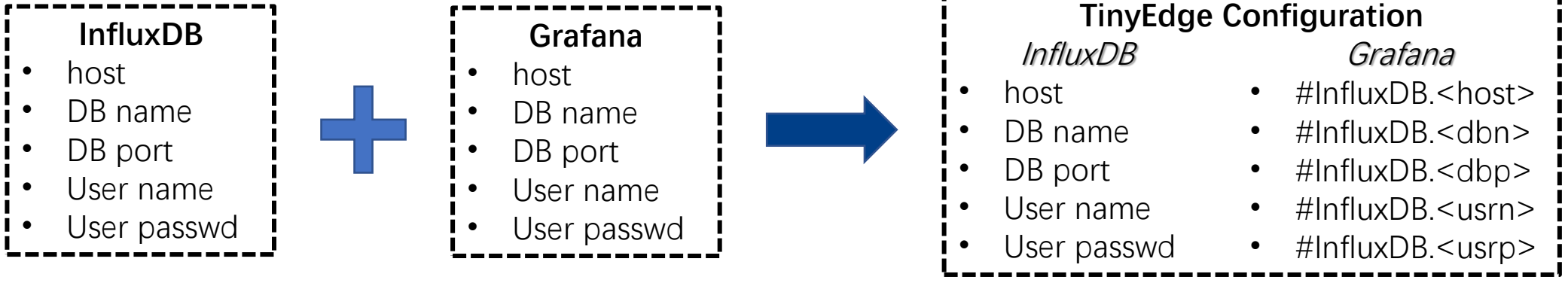
TinyEdge Customization Service - Configuration

- **Complex Configuration Items Within a Module**
  - Recall the example of the IoT application



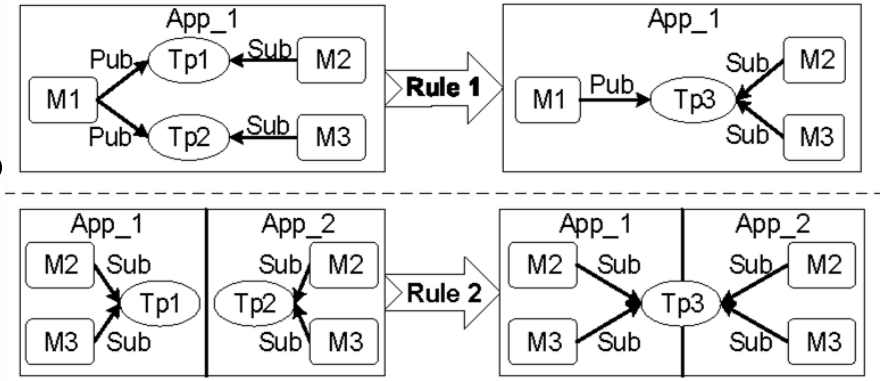
- **Redundant Configuration Items Across Modules**
  - Recall the example of the IoT application



TinyEdge Customization Service - DSL

- **Grammar of TinyEdge DSL**
  - Module function call
  - Message routing
    - Pub()/Sub()
  - Serverless function
    - Serverless()/get_results()
- **Dynamic Topic Generation**
  - Performance issue
    - # of Topics ↑ → Throughput ↓ Resources ↑
  - Generation rules
    - 1. Define **1** topic multi-sub of **single** pub in **1** APP
    - 2. Merge topics with the **same** sub in **1** SYS

```
1  from tinyedge.modules import mqtt, influxdb, grafana
2  from tinyedge.utils import Serverless
3
4  MQTT_Connector = mqtt("emq")
5  data = MQTT_Connector.get_data("device_id")
6  topic_id_1 = MQTT_Connector.Pub(data)
7  func = Serverless(language={"name":"python", "version":"
       3.6"}, package=[{"numpy":"1.14"}], path)
8  func.Sub(topic_id_1)
9  data = func.get_results(**args)
10 topic_id_2 = func.Pub(data)
11 Influx = influxdb("influxdb")
12 data = Influx.Sub(topic_id_2)
13 InfluxDB.insert(data)
14 Grafana = grafana("grafana")
15 data = Grafana.Sub(topic_id_1)
16 Grafana.visualize(data)
```



TinyEdge Performance Estimation Service

- **Module Profile** influxdb
  - Configuration: Basic/Advanced | User
  - Functionality: Read/Write | Built-in
  - Performance model: Path | User
  - Resource requirement: Memory/Storage | User
- **Estimation Models** MQTT.ORG IMAGENET
  - Workload model
    - workload vector + hardware specs.
  - Latency model
    - Connecting/Processing modules
      - Data I/O size + RTT + exec + wait
    - $M^{\alpha}/M^{\beta}/C$ queuing model

```
"config":{
  "basic":[{"port":8086}, {"dbn":"test"}],
  "adv":[{"adm":True}, {"admp":8083}],
 }
"func":[
  {"read": read()}, {"write": write()},
]
"model":[
  {"load": "/iflx_w"}, {"latency": "/iflx_t"},
]
"requirement":[
  {"mem": "20MB"}, {"vol": "260MB"},
]
```

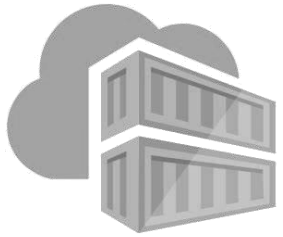
Implementation

- **Overall Architecture**

Cloud

Customization, Estimation Backend

HW Specs, Module Profile Database



Container Registry

Connector
MQTT,HTTP, Modbus, Bluetooth

Database
InfluxDB, MySQL, Redis, SQLite

System
Device Mgmt, Grafana, Kafka, Serverless

Data Analysis
Obj Recog, ALPR, Filter, Car Tracking, Vibration Detection

Edge

TinyEdge Runtime

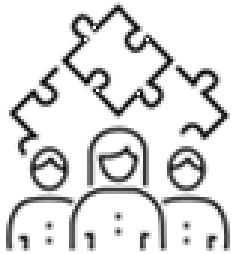
Deployment Tools

Customized System

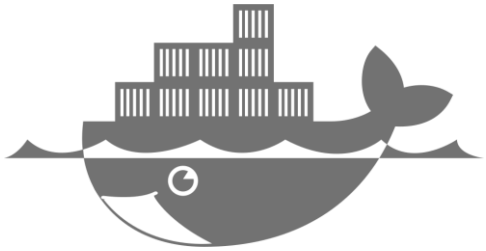
Evaluation

- **Baseline**
  - Azure IoT Edge (Industry), EdgeX (Open-source community)

Maturity

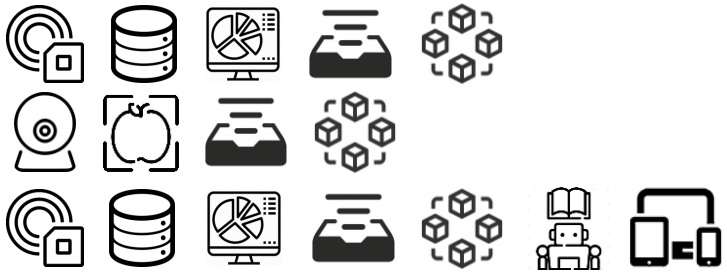


Third-party Support



Docker Backbone

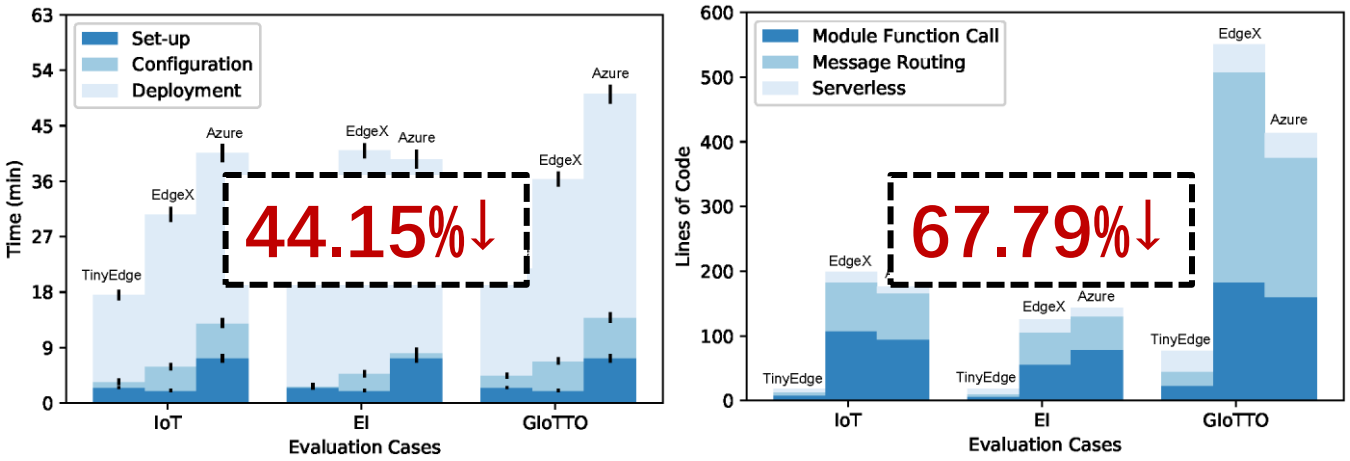
- **Cases**
  - Data connection and visualization (IoT)
  - Intelligent data processing (EI)
  - A hybrid-analysis system (GIoTTO[1])

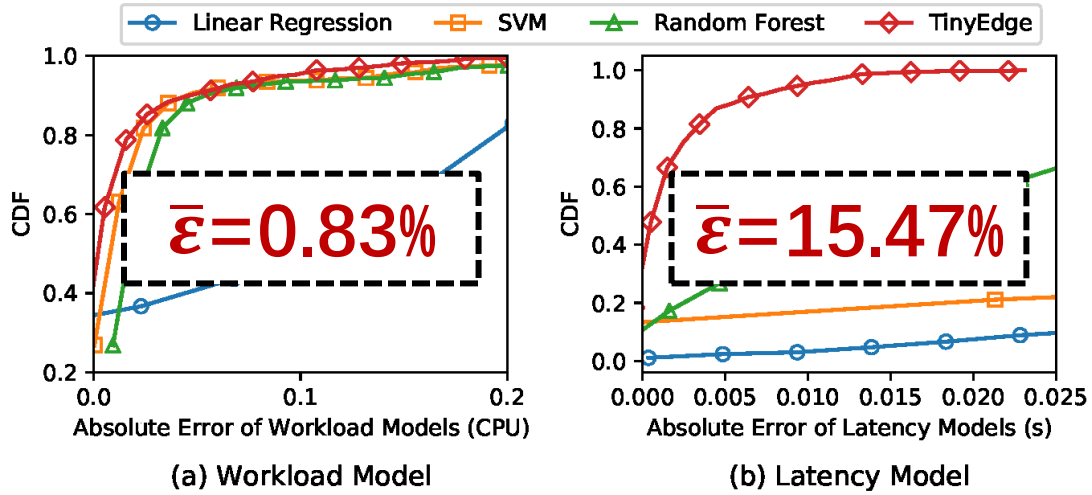


[1] IoT Expedition: A large-scale deployment of Internet of Things that is extensible, privacy-sensitive, and end-user-programmable. Online Available: https://iotexpedition.org/

Evaluation

- **Customization**
  - Overall time reduction
    - 1. Environment set-up
    - 2. Module configuration
    - 3. System deployment
  - Lines-of-code reduction
- **Performance Estimation**
  - Baseline models
    - Linear regression
    - SVM
    - Random forest
  - Data size: 1.5k/0.5k each case





TinyEdge

A *rapid* customization approach for edge systems target at IoT applications:

- *Full-stack optimizations* → *Faster customization*
- *2 types of models* → *Better performance awareness*

Thanks for your attention!

Q & A

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