Effect-Driven Selection of Web of Things Services in Cyber-Physical Systems Using Reinforcement Learning

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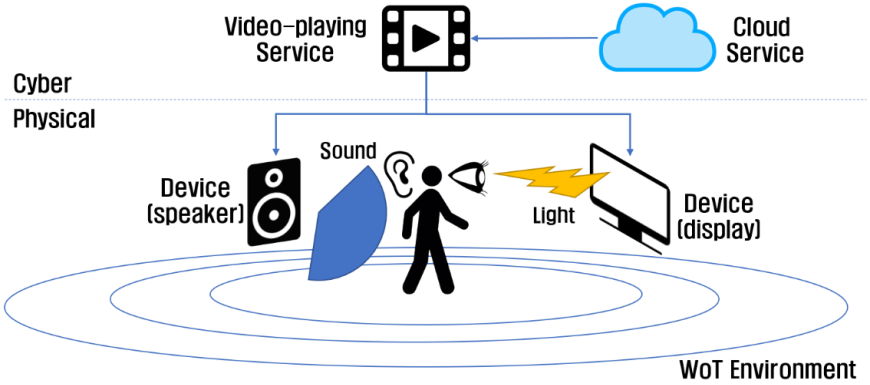
Introduction

CPS-based Web of Things Environments

- **Web of Things service**
  - "The **Web of Things** (**WoT**) is software architectural styles and programming patterns that allow real-world objects to be part of the World Wide Web." [1]
  - Providing services to the user by utilizing connected things
- **Cyber-Physical System (CPS)**
  - "A **cyber-physical system (CPS)** is a mechanism that is controlled or monitored by computer-based algorithms, tightly integrated with the Internet and its users." [2]

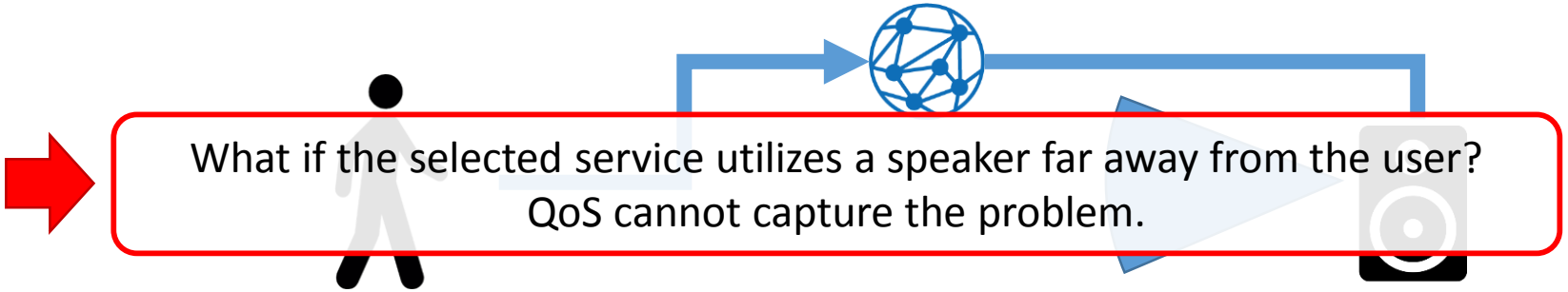


[1] https://en.wikipedia.org/wiki/Web_of_Things [2] https://en.wikipedia.org/wiki/Cyber-physical_system

Important Characteristic of WoT Services and Problem

- **Physical effect delivery**
  - Physical effects (ex. light, sound) generated by things should be delivered to the user and being perceived by the user properly
  - User satisfaction of service is affected by quality of effect delivery

- **Web service selection problem**
  - Selecting best service among functionally equivalent candidates
  - In terms of network-level Quality of Service (QoS)
    - Availability, transmission delay, packet loss…



Suggesting Solution

- **Effect-driven selection of WoT services**
  - Selecting optimal services in terms of quality of physical effects
  - The user will evaluate the quality,
    and a selection algorithm should be able to predict the evaluation

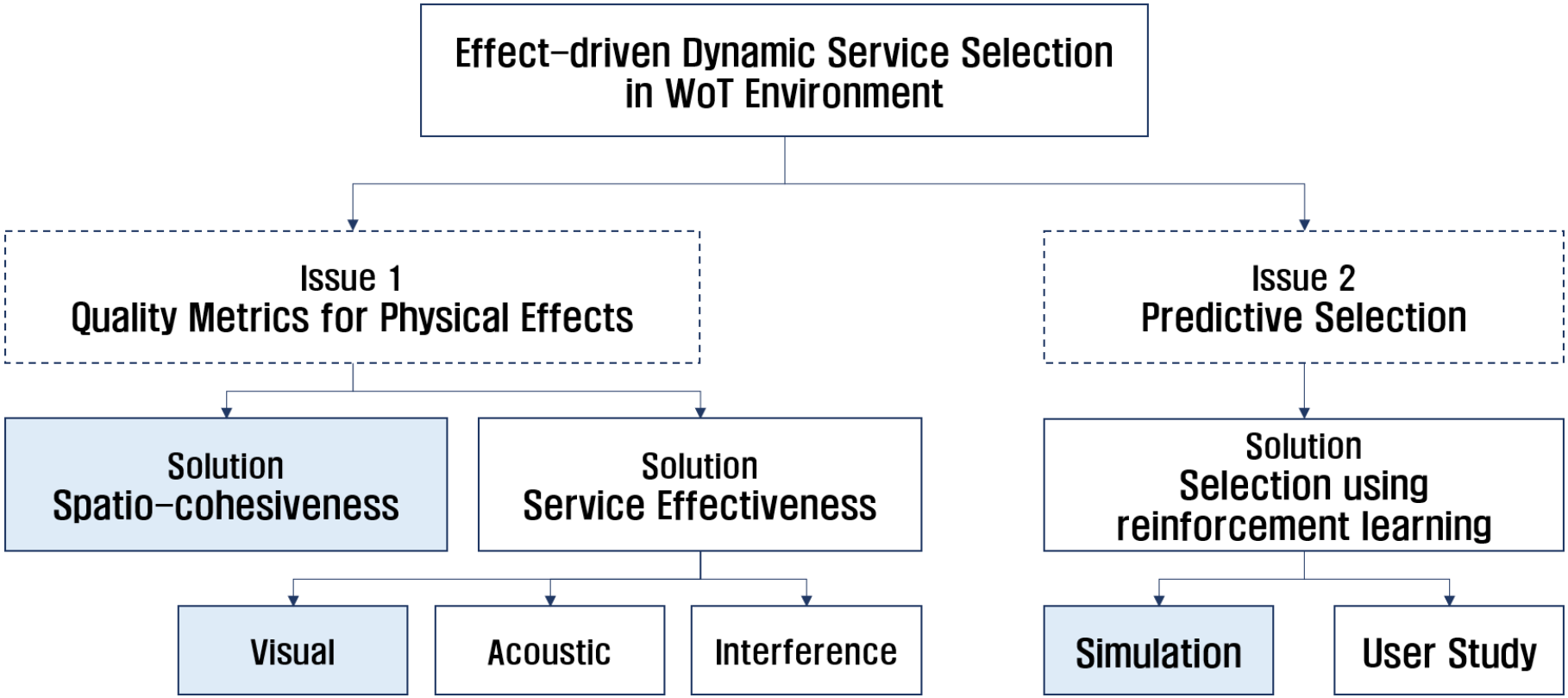
How to measure quality of physical effects in the user's perspective? → Service effectiveness model

- **Dynamic selection of WoT services**
  - Dynamically selecting and replacing services to maintain high effectiveness continuously

How to select services in a predictive manner to deal with mobile users/devices? → Dynamic service handover

Research Issues

Research Roadmap



Research Issues (Service Effectiveness)

- **Computation model of service effectiveness**
  - Enable quantitative predicting the service effectiveness
    - Selection is done automatically according to the prediction
  - Different service/effect type may have different model
    - Light, sound, heat, …

- **Service interference model**
  - Same or different type of physical effects may cause interferences
    - Constructive (synergy)
    - Destructive (disturbance)
  - Develop interference-aware effectiveness model for multi-services

Research Issues (Dynamic Service Handover)

- **Dynamic service handover algorithm [1]**
  - Existing approaches do not consider dynamically changing environments
    - ➢ Users and services in WoT environments are highly dynamic
  - Replacing service instance within another one to maintain high quality throughout the service provision
  - Extension of network-level handover concept to service-level

- **Predictive selection algorithm**
  - Predict future conditions of candidate services and select the most promising one
    - ➢ Reducing the number of service handover

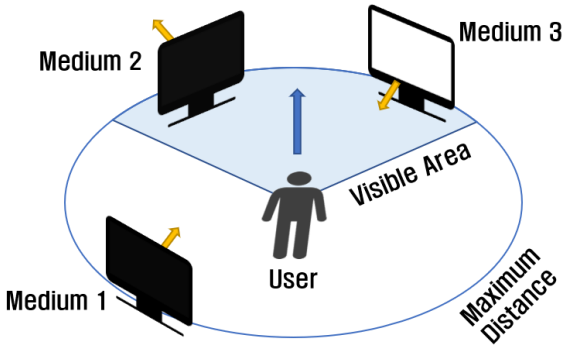
[1] **Baek, Kyeong-Deok**, and In-Young Ko. "Spatially cohesive service discovery and dynamic service handover for distributed IoT environments." *International Conference on Web Engineering*. Springer, Cham, 2017.

Previous Works

Previous Works (Service Effectiveness)

- **Spatio-cohesiveness [1, 2]**
  - Measure how the selected devices are spatially cohesive
    - ✓Assume highly cohesive devices are likely to provide high quality of physical effects, because of locality
  - [Limitation] Short distance cannot guarantee effectiveness

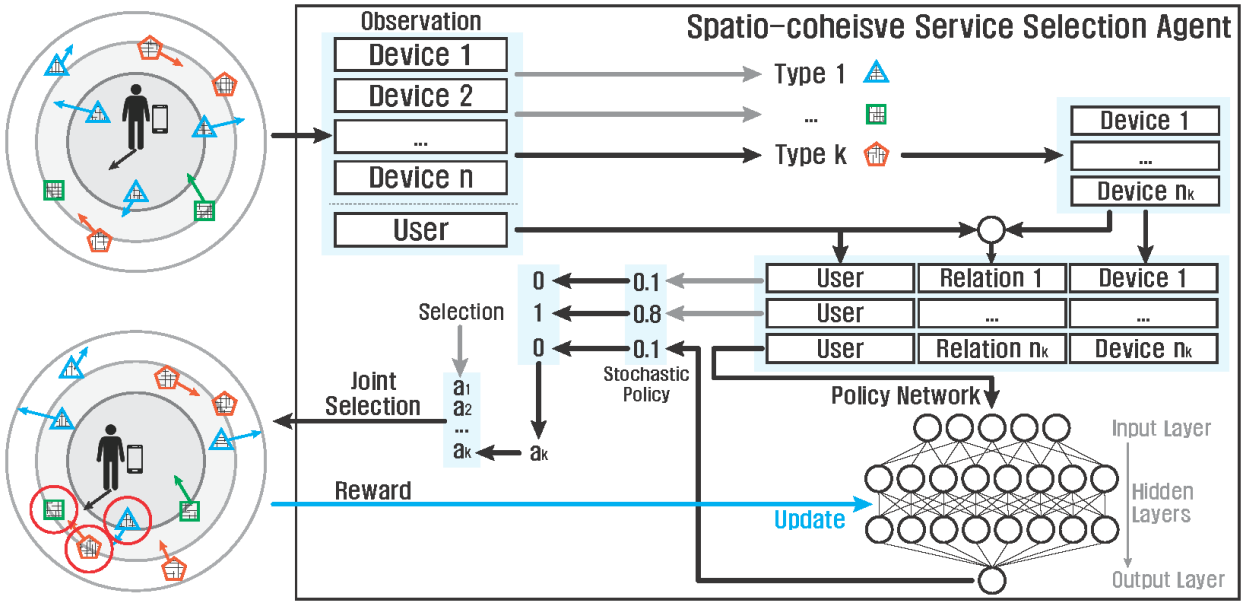
- **Visual service effectiveness [3]**
  - Rule-based model that measure whether a user can read texts on a display
    - ✓Distance, Field of View (FoV), Facing rule



[1] **Baek, Kyeong-Deok**, and In-Young Ko. "Spatially cohesive service discovery and dynamic service handover for distributed IoT environments." International Conference on Web Engineering. Springer, Cham, 2017.
[2] **Baek, KyeongDeok**, and In-Young Ko. "Spatio-Cohesive Service Selection Using Machine Learning in Dynamic IoT Environments." International Conference on Web Engineering. Springer, Cham, 2018.
[3] **Kyeongdeok Baek**, and In-Young Ko, "**Effect-driven Dynamic Selection of Physical Media for Visual IoT Services using Reinforcement Learning**", To appear in Proceedings of the 24th IEEE International Conference on Web Services (ICWS 2019), July 8 – 13, 2019, Milan, Italy

Previous Works (Dynamic Service Handover)

- **RL-based dynamic service selection (handover) algorithm [1, 2]**
  - Perform predictive and dynamic selection on services
    - ➢ Learn from experiences to select most promising service
  - Tried actor-critic algorithm [1] and DQN algorithm [2]



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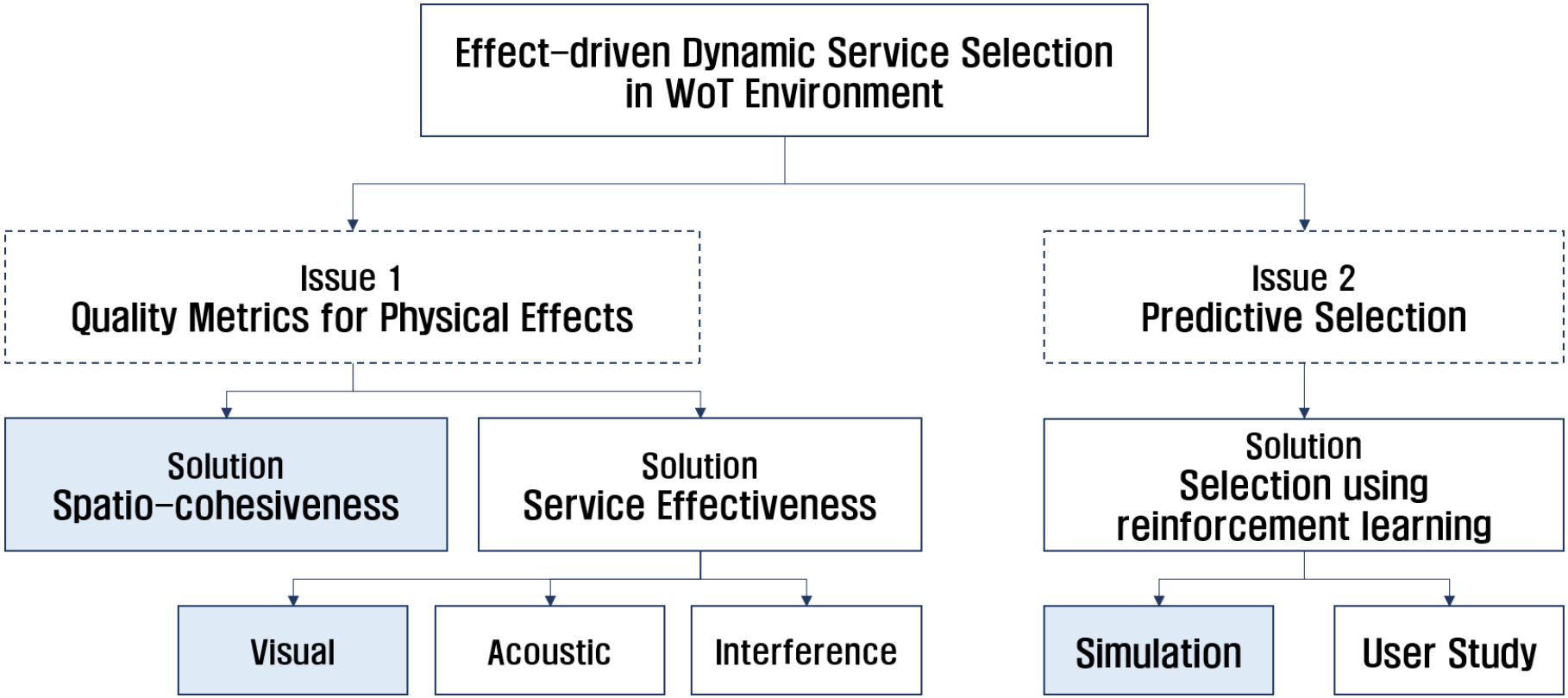
Research Plan

Research Roadmap (Remind)



Research Plan (Service Effectiveness)

1. Type-specific service effectiveness model

- Develop service effectiveness model for each type
  - ➢ Currently, only visual model is partially developed [1]
- Action items
  1) Acoustic service effectiveness model
  2) Improve visual service effectiveness model

2. Service interference model

- Analyze service interference among the services that generate similar or different types of physical effects
- Action items
  1) Develop interference prediction model

[1] **Kyeongdeok Baek**, and In-Young Ko, "Effect-driven Dynamic Selection of Physical Media for Visual IoT Services using Reinforcement Learning", To appear in Proceedings of the 24th IEEE International Conference on Web Services (ICWS 2019), July 8 – 13, 2019, Milan, Italy

Research Plan (Dynamic Service Handover)

1. **Virtual Reality-powered user study**
   - Perform user study for
     - Evaluating practicality of our approach
     - Collecting realistic data from real users
   - VR-powered simulation for cost-efficiency
     - ICWE 2019 Demo [1]

2. **Learn from human preferences**
   - Rather than using reward signals, guided by human preferences [2]
   - Applying latest RL techniques

[1] **Baek, KyeongDeok**, HyeongCheol Moon, and In-Young Ko. "VR-Powered Scenario-Based Testing for Visual and Acoustic Web of Things Services." International Conference on Web Engineering. Springer, Cham, 2019.
[2] Christiano, P.F., Leike, J., Brown, T., Martic, M., Legg, S., Amodei, D.: Deep reinforcement learning from human preferences. In: Advances in Neural Information Processing Systems, pp. 4299–4307 (2017)

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- [2] **Baek, KyeongDeok**, and In-Young Ko. "Spatio-Cohesive Service Selection Using Machine Learning in Dynamic IoT Environments." International Conference on Web Engineering. Springer, Cham, 2018.
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- [5] **Baek, KyeongDeok**, HyeongCheol Moon, and In-Young Ko. "VR-Powered Scenario-Based Testing for Visual and Acoustic Web of Things Services." International Conference on Web Engineering. Springer, Cham, 2019.
- [6] **Baek, KyeongDeok**, and In-Young Ko. "Effect-Driven Selection of Web of Things Services in Cyber-Physical Systems Using Reinforcement Learning." International Conference on Web Engineering. Springer, Cham, 2019.

Thank you

- Q&A
- Comments