# Contextual Variability Management of IoT Applications Using Agent-Base Modeling with Software Product Line

**Asad Abbas[1], Hyung-Lak Kim[2], Isma Farah Siddiqui[3], Ali Kashif Bashir[4], Scott Uk-Jin Lee[5*]**

[1,2,5] Department of Computer Science and Engineering, Hanyang University, South Korea
[3] Department of Software Engineering, Mehran University of Engineering and Technology, Pakistan
[4] Department of Science and Technology, University of the Faroe Islands, Faroe Islands, Denmark
*{asadabbas, koliaok, isma2012,* **scottlee}@hanyang.ac.kr,** *alib@setur.fo*

## Abstract

IoT (Internet of Things) is used to connect the real-world objects that communicate with internet. IoT applications enable to handle and operate the device according to environment requirements such as transport and health care. IoT devices are interconnected with multiple agents that operate as median entity to communicate between internet devices. Agent applications enable the IoT usage within environmental variations i.e. operation of heat sensor varies indoor and outdoor. In this paper, we have proposed modeling of IoT agents and applications by using Software Product Line (SPL) feature modeling. XML-based feature modeling is appropriate to handle the contextual variability within the same domain of applications and increase the reusability of features. We have adopted XML for modeling the IoT application, agents and internet device for contextual variability management.

**Index Terms**: IoT Agents, IoT Applications, Software Product Line, Feature Model.

## I. INTRODUCTION

IoT (Internet of Things) are used anywhere anytime with any internet device to achieve the respective goals. IoT enables interaction to communicate with different devices to exchange the data and information sensed by the environment. In real world, IoT is used in different business, health and transportation systems to facilitate the end users on runtime data and information. Therefore, IoT is the combination of multiple internet devices that consider the environment presence for real time services by using IoT applications [1].

IoT applications enable the devices to operate according to environment. Due to huge number of internet devices interaction, applications become complex and hard to manage [2]. IoT application modeling is important factor to create the interaction between devices. These applications communicate with the agents of internet system and internet devices also respond to IoT by using these agents. Therefore, precise modeling of IoT applications and agents enable the communication more accurate. Furthermore, reusability of IoT features according to environment increase the productivity, time to market and less cost such as air corn indoor and outdoor is same with different applications due the different

temperature sensing [3]. Software Product Line (SPL) is used for development of multiple products from same domain but different variation point according to environment [4].

SPL consist on two processes, Domain Engineering: all possible features with relationships (mandatory, alternative, optional and OR group) that can be part of final multiple products, Application Engineering: features selection from domain to develop the final product according to environment and end user requirements [5, 6]. Feature modeling is highly used in Software Product Line (SPL) for products development in same domain. IoT applications and agents also consist on multiple common and variable features [4]. In this paper, we have proposed feature modeling for IoT applications and agents to increase communication accuracy, reusability of features, time to market and development with less cost. Therefore, in this paper we have used SPL feature model to increase the reusability of common and variable features for IoT applications and agents. We used XML-schema for modeling of IoT-based applications and agents. XML-schema covers all cardinality constraints of feature model such as alternative, optional and OR group.

Paper structure is as follows: Section II is related Work, Section III is Agent-Base Modeling of IoT Applications and Section IV is Conclusion.

## II. RELATED WORK:

Ayala et. al. proposed SPL process for the development of IoT multi-agents to increase the reusability of IoT features in future products. For multi-agent development, Self-StarMASMAS is appropriate technique to interconnect and communication between features of IoT applications and system. Author used Common Variability Language to handle the contextual variability of IoT-based feature model according to environment. StarMASMAS with SPL increased the productivity and accuracy of environmental feature selection for IoT multi-agent application development [3].

Endler et. al. presented stream-based reasoning for IoT application development on large and complex systems. Bare bones are used on data level for actuation and sensing IoT systems. However, large scale applications require high level contextual awareness for system reasoning on physical environment. In stream-based reasoning, machine learning is used for environment understanding and select the appropriate features for final IoT application development [7].

Ayala et. al. presented StarMASMAS for Ambient Assisted Living (AAL) IoT application with multi-agent systems. The aspect is to manage the devices that are laying heterogeneity in system to facilitate the communication. In different IoT devices, mostly focus on degradation, loss of energy and network failures. However, IoT applications required more accurate communication between internet devices [8].

Kim et. al. presented the XML language for modeling the IoT applications. XML-schema is used for meta-model (relationship and constraints) of features and convert to XML document for feature connections. Different applications used multiple protocols in internet and hard to manage the communication in different platform protocols. XML language is appropriate for modeling the multiple protocols in same IoT system that communicates outside the domain [9].

## III. AGENT-BASE MODELING OF IOT APPLICATION:

Feature modeling of SPL is best paradigm to manage the commonalities and variability of multiple products from same domain. We have presented the presented the processes of SPL for IoT-based agents and applications as shown in fig. 1. Domain engineering is first step where all features (common and variable), constraints and relationships need to define of IoT domain and agents. Furthermore, identify the variation points that create the variability in final products according to environment and end user requirements. Finally, in domain engineering, a common feature model is developed for all IoT applications and agents that satisfy the relations and constraints. IoT application engineering is the features selection process from variability that are required by end user. Application features interacts with agent application features and select features that are feasible and compatible with actual IoT application as shown in fig. 2. We have used Car-Product-Line sensor that is required for safety purposes and sensor agent for communication between car sensing unit and sensing applications.

We used XML-schema for modeling of IoT sensor agent and application components. As shown in fig. 3, all features of car sensors are interconnected and communicate with sensor application by using sensor agent. Car sensor develops architecture automatically from sensor application according to environment selection or end user requirements.

## IV.CONCLUSION:

In this paper, we have proposed IoT application and agent modeling technique by using SPL feature model. SPL increase the reusability of IoT features due to developed domain assets. IoT Agents communicate with IoT application and internet devices in different environments. Therefore, by handling the environmental variability of IoT application increase the correct communication and productivity. We used XML-schema for modeling the environmental variability by using SPL feature model and correctly communicate IoT sensor application features via agent features.

## ACKNOWLEDGMENT

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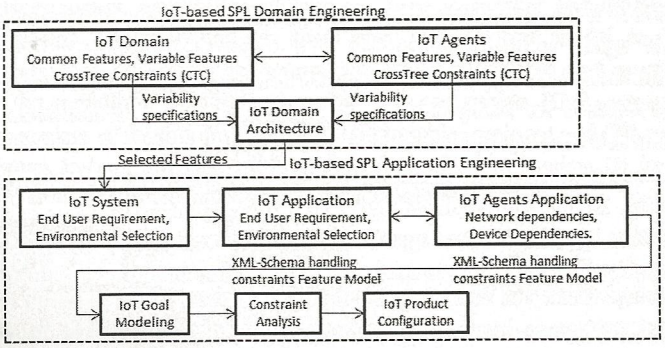


**Fig. 1. SPL process for IoT-based applications and agents**

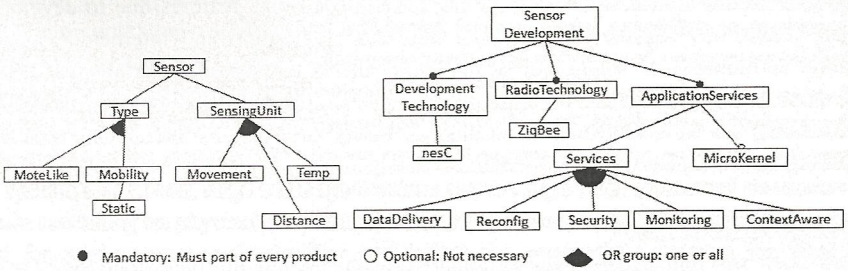


**Fig. 2. a) Sensor Agent FM b) Sensor Development Application FM**

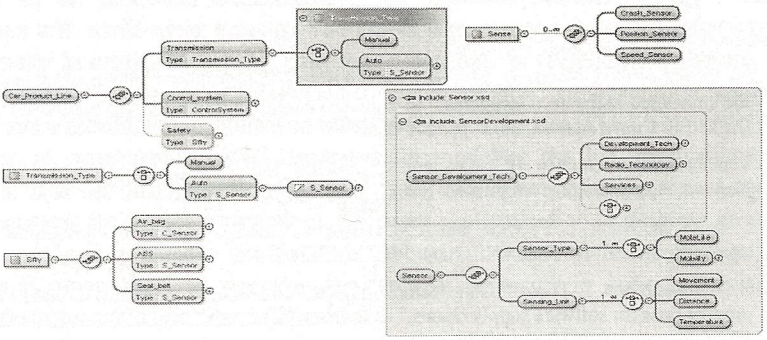

**Fig. 3. XML-Schema modeling of Car Sensor Product Line**