ITE Arbitrator: A Reference Architecture Framework for Sustainable IT Ecosystems

Soojin Park, SIAT, Sogang University, Seoul, South Korea (psjdream@sogang.ac.kr)

Young B. Park, Department of Computer Science & Engineering, Dankook University, Seoul, South Korea (ybpark@dankook.ac.kr)
Research Background
Paradigm: A Single System → System of Systems
An **IT Ecosystem** is a complex system compound composed of interactive and autonomous individual systems, adaptive as a whole based on local adaptivity [1].
MAPE-K loop

Autonomic Manager

Analyze

Plan

Monitor

Execute

Knowledge

Managed resource touchpoint

Sensors

Effectors

Managed resource
Related Work
Related Work

- **Rainbow [5]**
  - Introduces a reusable infrastructure as to separate concerns between adaptation and application logic
  - Provides architecture-based self-adaptability
  - Limited to use when situation-specific action rules are applicable.

- **MUSIC [6]**
  - Combines previous component-based development methods with Service Oriented Architecture (SOA)
  - Responds to the distributed and dynamic requirements in mobile environments
  - Limited in its need for manual adaptation plan update or replacement because the framework does not include goal management features in its MAPE-K self-adaptation layers

- **DiVA [7]**
  - Provides methodologies and framework for developing self-adaptive systems and for managing variability of self-adaptive systems
  - Based on the characteristics of aspect-oriented programming
Common Limitation of Related Work
- Self-adaptation is limited to single systems with focus on local adaptation
- They are dealing with a MAPE-K loop in a single system

We propose…
- A reference architecture framework to support **not a single system but an IT ecosystem.**
- **The proposed reference architecture framework** includes:
  - An **orchestration mechanism** to select an optimal configuration against environment contexts
  - The selection is based on a **cost-benefit model** to evaluate each configuration of participatory systems
  - To minimize the overhead of running the MAPE-K loop, we adopt **genetic algorithms** in generating candidate configurations
An Overview of *ITE Arbitrator*
Two different kinds of goal models should be provided to specify

- The **autonomy aspect** of individual participant systems in the IT ecosystem
- The **controllability aspect** of the entire IT ecosystem

Two different loops for achieving the two different types of goals should be supported

- **N number of MAPE-K loops** to control individual participants systems
- **A MAPE-K loop** to control the entire IT ecosystem

The role of executing the different loops must be explicitly separated
Hierarchical Control Pattern [3]

- **Motivation**
  - The loops can work at different time scales and manage different kinds of resources, and resources with different localities.
  - Control loops need to interact and coordinate actions to avoid conflicts and provide certain guarantees about adaptations.

- **Solution**: Provides a layered separation of concerns to manage the complexity of self-adaptation.
Conceptual Architecture of *ITE Arbitrator*

**Orchestration Layer**
- **<<Role>> TeamLeader**
  - Analyze
  - Generate Orchestration Model
  - Monitor
  - Change Configuration
  - Execute

**Service Layer**
- **<<Role>> TeamMember**
  - App.

**Generic Orchestration Goal Model**
- Run Optimal Participants
- Monitor System Indicators
- Detect Inability of Participant(s)
- Change Participants
- Plan Reconfiguration

**A Piece of a Specific Service Goal Model**
- Gardening
- Monitor Drought
- Supply Water

**Collaborative Communication Layer**
- Operators
- System Indicators
Conceptual Reference Architecture of ITE Arbitrator

Orchestration Layer
- Analyze
- Plan
- Execute

<<Role>> TeamLeader
- Generate Orchestration Model
- Analyze Problems in Orchestration Model
- Plan to Solve Problems

Global ITE Knowledge
- Monitor
- Change Configuration

System Indicators
- Operators

Collaborative Communication Layer

Service Layer
- <<Role>> TeamMember
  - App. S A

Generic Orchestration Goal Model
- Run Optimal Participants
- Plan Reconfiguration
- Change Participants
- Monitor System Indicators
- Detect Inability of Participant(s)

A Piece of a Specific Service Goal Model
- Gardening
- Monitor Drought
- Supply Water

App. S A
Conceptual Reference Architecture of **ITE Arbitrator**

1. **TimeOut()**
2. **MonitorCurrentCollaboration()**
3. **InvestigateMembers**

**Loop**

4. **GetStatus()**
5. **GetStatus()**
6. **GetStatus()**

**Loop**

7. **UpdateParticipants()**

**Loop**

8. **MonitorEnvironment()**
9. **GetEnvironmentProperty()**

10. **UpdateEnvironments()**

11. **CalculateCollaborationScore**
    
    (Participants[], Environments[])

12. **SelectOptimalConfigSet()**

13. **Reset()**

**opt IF collaborationScore < Threshold**
A Case Study Scenario: The Unmanned Forest Management IT Ecosystem (UFM IT Ecosystem)
UFM IT Ecosystem: Environment Model

Environment Model: Forest

- Forest
  - 1..* Zone
    - Weather Condition
    - Visibility
    - Wind Velocity
    - Forest Density
    - Zone Type
    - Length
    - Breadth
  - 0..* Lake
    - Extent
  - 0..* Mountain
    - Height
  - 0..* River
    - Width
<table>
<thead>
<tr>
<th>Zone Type</th>
<th>Weather Condition</th>
<th>Visibility</th>
<th>Wind Velocity</th>
<th>Forest Density</th>
<th>Weather Condition</th>
<th>Visibility</th>
<th>Wind Velocity</th>
<th>Forest Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>[0]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[1]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[2]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>has Field</td>
<td>Cloudy</td>
<td>10 Km</td>
<td>5 m/s</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>has Field</td>
<td>Cloudy</td>
<td>8 Km</td>
<td>8 m/s</td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>has Mountain</td>
<td>Rainy</td>
<td>7 Km</td>
<td>15 m/s</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>has Field</td>
<td>Cloudy</td>
<td>11 Km</td>
<td>5 m/s</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>has Lake</td>
<td>Cloudy</td>
<td>4 Km</td>
<td>25 m/s</td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>has Mountain</td>
<td>Rainy</td>
<td>3 Km</td>
<td>21 m/s</td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>has River</td>
<td>Sunny</td>
<td>23 Km</td>
<td>5 m/s</td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>has River</td>
<td>Sunny</td>
<td>16 Km</td>
<td>22 m/s</td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>has Field</td>
<td>Cloudy</td>
<td>11 Km</td>
<td>15 m/s</td>
<td>High</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Instances of a Forest

UFM IT Ecosystem: Environment Model
Unmanned Forest Management

Gardening
- Monitor Drought
- Supply Water

Rescue Sufferer
- Detect Sufferer
- Locate Sufferer
- Move Sufferer

Fight Fire
- Detect Fire
- Make Roads
- Supress Fire

And

And

And
UFM IT Ecosystem: Instantiated Roles

- **Collaboration Group**: Gardeners
  - **Role**: Chief Gardener
    - Achievements: SupplyWater, MonitorDrought
  - **Role**: Gardener
    - Achievements: SupplyWater
  - **Role**: Surveillant
    - Achievements: MonitorDrought
- **Role**: TeamLeader
  - Capabilities: MonitorCurrentCollaboration, InvestigateMembers, UpdateParticipants, UpdateEnvironments, CalculateCollaborationScore, SelectOptimalConfigSet
- **Role**: TeamMember
  - Capabilities: GetStatus, MonitorEnvironment

**Service goals for UFM IT Ecosystem**

**Generic capabilities for orchestration goals**

**Generic Roles In ITE Arbitrator**
UFM IT Ecosystem: An Example of Participant System

Utilizing Costs & Benefits

Available Roles

Capabilities

<<Participant>>
Helicopter

<<cost>> OperationCost
<<cost>> DeprecationCost
<<cost>> FuelCost
<<benefit>> MonitoringDistance

<<play>>Gardener
<<play>>Surveillant
<<play>>Chief Gardener

<<Capability>>
GPS

<<Capability>>
Vision

<<Capability>>
Infrared

<<Capability>>
Sprinkler
<<action>> DropWater

<<Capability>>
Sensor

<<Capability>>
Actuator
<<action>> GetStatus
<table>
<thead>
<tr>
<th>ID</th>
<th>Type</th>
<th>Cost</th>
<th>Benefit</th>
<th>O</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A  B  D  E  F  G</td>
<td>H  I  J  K  L  M  N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>JE1</td>
<td>Jeep</td>
<td>40 40 14 60 32 19</td>
<td>0.7 0.6 0.64 100 87 74 46</td>
<td>30</td>
<td>80</td>
</tr>
<tr>
<td>JE2</td>
<td>Jeep</td>
<td>40 40 15 35 37 22</td>
<td>0.59 0.35 0.73 100 78 54 54</td>
<td>25</td>
<td>69</td>
</tr>
<tr>
<td>JE3</td>
<td>Jeep</td>
<td>40 40 12 64 39 23</td>
<td>0.98 0.64 0.78 100 96 57 47</td>
<td>27</td>
<td>63</td>
</tr>
<tr>
<td>JE4</td>
<td>Jeep</td>
<td>40 40 13 76 35 21</td>
<td>1 0.76 0.7 100 86 58 46</td>
<td>37</td>
<td>79</td>
</tr>
<tr>
<td>JE5</td>
<td>Jeep</td>
<td>40 40 16 45 38 23</td>
<td>0.8 0.45 0.75 100 78 68 38</td>
<td>25</td>
<td>74</td>
</tr>
<tr>
<td>JE6</td>
<td>Jeep</td>
<td>40 40 16 85 47 28</td>
<td>0.93 0.85 0.93 100 84 72 51</td>
<td>31</td>
<td>84</td>
</tr>
<tr>
<td>UAV1</td>
<td>UAV</td>
<td>0 100 70 86 50 30</td>
<td>0.9 0.86 1 100 100 100 100</td>
<td>102</td>
<td>72</td>
</tr>
<tr>
<td>UAV2</td>
<td>UAV</td>
<td>0 100 75 100 50 30</td>
<td>0.95 1 1 100 100 100 100</td>
<td>86</td>
<td>68</td>
</tr>
<tr>
<td>HE1</td>
<td>Hlct</td>
<td>80 70 67 75 34 20</td>
<td>0.67 0.75 0.68 100 87 100 74</td>
<td>120</td>
<td>62</td>
</tr>
<tr>
<td>HE2</td>
<td>Hlct</td>
<td>80 70 56 60 43 26</td>
<td>0.87 0.6 0.85 100 87 100 78</td>
<td>116</td>
<td>83</td>
</tr>
<tr>
<td>AP1</td>
<td>AP</td>
<td>100 80 80 63 37 22</td>
<td>0.62 0.63 0.74 100 87 100 86</td>
<td>170</td>
<td>73</td>
</tr>
<tr>
<td>AP2</td>
<td>AP</td>
<td>100 80 83 73 47 28</td>
<td>0.84 0.73 0.93 100 83 100 87</td>
<td>150</td>
<td>86</td>
</tr>
</tbody>
</table>

(A) Cost for operating the unmanned vehicle system by human ($/hr)
(B) Deprecation cost ($/hr)
(D) Fuel expenses ($/hr)
(E)–(G) Deprecation cost of Sensors ($/hr): (E) vision sensor, (F) infrared sensor, and (G) GPS sensor.
(H)–(J) Sensitivity of Sensors(0..1): The normalized sensitivity degree of sensors: (H) vision sensor, (I) infrared sensor, and (J) GPS sensor.
(K)–(N) Monitoring Scope (km/hr): It is different according to the geographic property and weather condition shown in ForestZone[ ][].
(O) Remained Fuel Quantity (l)
(P) Availability Degree (%)
Violation Rules for Assignment of Participants

- **IF** (zone[][].visibility < 5 (km)) **THEN** Helicopter **CANNOT PLAY AS** Surveillant **AT** zone[][]
- **IF** (zone[][].windVelocity > 20 (m/s)) **THEN** (UAV & Helicopter & AirPlane) **CANNOT PLAY AS** Surveillant **AT** zone[][]
- **IF** (zone[][].weatherCondition = Snowy) **THEN** Jeep **CANNOT PLAY AS** Surveillant **AT** zone[][]
- **IF** (zone[][].type = hasLake or hasRiver) **THEN** Jeep **CANNOT PLAY AS** Surveillant **AT** zone[][]
- **IF** (zone[][].forestDensity = High) & (zone[][].Participant) = Jeep) **THEN** Jeep should be operated by a human driver
- **IF** (participant. remainedFuelQuantity < Required Quantity for Running One Period) **THEN** Participant **CANNOT PLAY** any role **AT** any zone
An Instantiated Architecture of *ITE Arbitrator*:
UFM IT Ecosystem
An Instantiated Architecture for Team Member

Service Layer
- Weather Monitor
- Weather Change Analyzer
- PullOut Planner

Context Monitor
- activate()
- timeOut()
- get_Local_Env()

Adaptation Analyzer
- analyze(Gauge)
- replan(Diagnosis)
- get_Global_Env()

Adaptation Planner
- execute(adaptation Plan)

Adaptation Executor
- set_NewConfig(Local_Config)

Global ITE Knowledge
- Global Environment
- Participants Profile
- Constraints & Rules
- ITE Configuration Manager

MAPE Core Bundle
- Felix
- Felix Service
- get_newConfig()

Felix Service Client
- Application (Controller)
- Effector

Configuration Manager
- Bundle Registry
- Local Configuration

ITE Bridge Service
- External Participant Service
- External Resource Service
- Other ITE Participant

Android Platform
- Local Environment
- Probe
An Instantiated Architecture for Team Member
An Instantiated Architecture for Team Leader
An Instantiated ITE Arbitrator for UFM IT Ecosystem
Orchestration Mechanism of ITE Arbitrator for UFM IT Ecosystem
MAPE-K loop for Orchestration Layer of UFM IT Ecosystem

1. (HE2, zone[0][2]) commits violation due to the occurrence of turbulence
2. **Collaboration Monitor**: Generates the global collaboration score from the current global configuration
3. **Collaboration Analyzer**: Compares the current score with the threshold and identifies the invalid pair(s) to commit violation
4. **Collaboration Planner**: Generates candidate configurations using a **genetic algorithm** and selects optimal one among candidates
5. **ITE Configuration Manager**: Updates a new optimal configuration as the current one and sends operations to each participant system
Genetic Algorithm for Downsizing the Set of Candidate Configurations

- A *chromosome*: an array of bits as a standard representation of each candidate solution
- Bit strings for all kinds of attributes for the environments and the participant systems are included
- The genetic representation makes it possible to facilitate genetic operations

<table>
<thead>
<tr>
<th>Zone [%][0]</th>
<th>Zone [0][1]</th>
<th>Zone [0][2]</th>
<th>Zone [0][n-1]</th>
<th>Zone [1][0]</th>
<th>Zone [n-1][n-1]</th>
</tr>
</thead>
<tbody>
<tr>
<td>$G_{11}$</td>
<td>$G_{12}$</td>
<td>$G_{13}$</td>
<td>$\ldots$</td>
<td>$G_{1n}$</td>
<td>$G_{1n+1}$</td>
</tr>
</tbody>
</table>

(a) Chromosome Representation for Forest Zone [n][n]
Genetic Algorithm for Downsizing the Set of Candidate Configurations

- If the violation occurs in the current configuration, the genetic algorithm uses mutation and a crossover mechanism to generate another population.

- Since this next population is generated from the base populations, the size of the next generation can be controlled and the searching space can be limited to find the most optimal solution.

(b) Propagation of the Next Generation of Chromosome #1
Evaluation of Benefits from Using the Genetic Algorithm

- **Experimental Design**
  - Target domain: UFM IT Ecosystem
  - 3 x 3 forest zones (9 zones)
  - 12 candidate participant systems
  - 30 times of reconfiguration has been occurred

- **Without the Genetic Algorithm**
  - Average elapsed time: 43 sec.
  - Increasing the number of candidate participant systems:
    - 13 candidates → 39 minutes
    - 14 candidates → it doesn’t work
Using the Genetic Algorithm

- Average elapsed time: 20 msec. (43 sec. → 20 msec.)
- Increasing the number of candidate participant systems
  - Average elapsed time for selecting the first configuration is exponentially increased when the candidates are over 20
  - Average elapsed time for each re-configuration is gradually ascended against the growth of the number of candidates
Global Collaboration Score

- **Collaboration score** as a fitness function
  - A higher collaboration score for a chromosome indicates that chromosome’s **greater effectiveness** in the mapping between the paired participant and the environment.

- Utility Functions

\[
\text{cost}(p_i, e_j) = \sum_k (\eta_k \times Ncf_k) \quad \text{where} \quad \sum_k \eta_k = 1
\]

\[
\text{benefit}(p_i, e_j) = Nbf_k = \frac{(Bf_k - Bf_{\min})}{(Bf_{\max} - Bf_{\min})}
\]

\[
\text{score}(Conf_r) = w_0 \times \text{benefit}(Conf_r) + w_1 \times \text{cost}(Conf_r)
\]

\[\text{where} \quad \sum |\omega_i| = 1 \quad \text{and} \quad \prod \omega_i = -1\]

Global Collaboration Score = \[\sum_j \text{C.Score}(p_i, e_j)\]

where \((p_i, e_j)\) is optimal chromosome for \(e_j\)
Global Collaboration Score

\[
G_{11} \ G_{12} \ G_{13} \ldots \ G_{1n} \ G_{1n+1} \ldots \ G_{1(n*n)}
\]

\text{Environmental violation}

\[
\text{Cost}(p_i, e_j) = \sum_k (\eta_k \times Nc_f \kappa) \quad \text{where} \quad \sum_k \eta_k = 1
\]

\[
\text{Benefit}(p_i, e_j) = Nf_k = \frac{(Bf_k - Bf_{\min})}{(Bf_{\max} - Bf_{\min})}
\]

\[
\text{Score}(Conf_r) = w_0 \times \text{Benefit}(Conf_r) + w_1 \times \text{Cost}(Conf_r)
\]

\[
\sum |\omega_i| = 1 \quad \text{and} \quad \prod \omega_i = -1
\]
Global Collaboration Score

### Cost

<table>
<thead>
<tr>
<th>ID</th>
<th>Type</th>
<th>A</th>
<th>B</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>O</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>JE1</td>
<td>Jeep</td>
<td>40</td>
<td>40</td>
<td>14</td>
<td>60</td>
<td>32</td>
<td>19</td>
<td>0.7</td>
<td>0.6</td>
<td>0.64</td>
<td>100</td>
<td>87</td>
<td>74</td>
<td>46</td>
<td>0.7</td>
<td>0.6</td>
</tr>
<tr>
<td>JE2</td>
<td>Jeep</td>
<td>40</td>
<td>40</td>
<td>15</td>
<td>35</td>
<td>37</td>
<td>22</td>
<td>0.59</td>
<td>0.35</td>
<td>0.73</td>
<td>100</td>
<td>78</td>
<td>54</td>
<td>54</td>
<td>25</td>
<td>69</td>
</tr>
<tr>
<td>JE3</td>
<td>Jeep</td>
<td>40</td>
<td>40</td>
<td>12</td>
<td>64</td>
<td>39</td>
<td>23</td>
<td>0.98</td>
<td>0.64</td>
<td>0.78</td>
<td>100</td>
<td>96</td>
<td>57</td>
<td>47</td>
<td>27</td>
<td>63</td>
</tr>
<tr>
<td>JE4</td>
<td>Jeep</td>
<td>40</td>
<td>40</td>
<td>13</td>
<td>76</td>
<td>35</td>
<td>21</td>
<td>1</td>
<td>0.76</td>
<td>0.7</td>
<td>100</td>
<td>86</td>
<td>58</td>
<td>46</td>
<td>37</td>
<td>79</td>
</tr>
<tr>
<td>JE5</td>
<td>Jeep</td>
<td>40</td>
<td>40</td>
<td>16</td>
<td>45</td>
<td>38</td>
<td>23</td>
<td>0.8</td>
<td>0.45</td>
<td>0.75</td>
<td>100</td>
<td>78</td>
<td>68</td>
<td>38</td>
<td>25</td>
<td>74</td>
</tr>
<tr>
<td>JE6</td>
<td>Jeep</td>
<td>40</td>
<td>40</td>
<td>16</td>
<td>85</td>
<td>47</td>
<td>28</td>
<td>0.93</td>
<td>0.85</td>
<td>0.93</td>
<td>100</td>
<td>84</td>
<td>72</td>
<td>51</td>
<td>31</td>
<td>84</td>
</tr>
<tr>
<td>UAV1</td>
<td>UAV</td>
<td>0</td>
<td>100</td>
<td>70</td>
<td>86</td>
<td>50</td>
<td>30</td>
<td>0.9</td>
<td>0.86</td>
<td>1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>102</td>
<td>72</td>
</tr>
<tr>
<td>UAV2</td>
<td>UAV</td>
<td>0</td>
<td>100</td>
<td>75</td>
<td>100</td>
<td>50</td>
<td>30</td>
<td>0.95</td>
<td>1</td>
<td>1</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>86</td>
<td>68</td>
</tr>
<tr>
<td>HE1</td>
<td>Hlct</td>
<td>80</td>
<td>70</td>
<td>67</td>
<td>75</td>
<td>34</td>
<td>20</td>
<td>0.67</td>
<td>0.75</td>
<td>0.68</td>
<td>100</td>
<td>87</td>
<td>100</td>
<td>74</td>
<td>120</td>
<td>62</td>
</tr>
<tr>
<td>HE2</td>
<td>Hlct</td>
<td>80</td>
<td>70</td>
<td>56</td>
<td>60</td>
<td>43</td>
<td>26</td>
<td>0.87</td>
<td>0.6</td>
<td>0.85</td>
<td>100</td>
<td>87</td>
<td>100</td>
<td>78</td>
<td>116</td>
<td>83</td>
</tr>
<tr>
<td>AP1</td>
<td>AP</td>
<td>100</td>
<td>80</td>
<td>80</td>
<td>63</td>
<td>37</td>
<td>22</td>
<td>0.62</td>
<td>0.63</td>
<td>0.74</td>
<td>100</td>
<td>87</td>
<td>100</td>
<td>86</td>
<td>170</td>
<td>73</td>
</tr>
<tr>
<td>AP2</td>
<td>AP</td>
<td>100</td>
<td>80</td>
<td>83</td>
<td>73</td>
<td>47</td>
<td>28</td>
<td>0.84</td>
<td>0.73</td>
<td>0.93</td>
<td>100</td>
<td>83</td>
<td>100</td>
<td>87</td>
<td>150</td>
<td>86</td>
</tr>
</tbody>
</table>

Note: For simplicity, the table shows only a subset of the data. The full table is not shown here.
Global Collaboration Score

Current Participants

UnmannedForestMonitor

Selected Participants Configuration
(JE5, JE1, UAV1, JE3, UAV2, JE2, HE2, HE1, JE6)
Cost: 3.47 / Benefit: 7.95 / C.Score: 4.48

Available Participants Configuration
(JE5, JE2, UAV1, JE4, AP1, JE3, HE2, HE1, JE6)
Cost: 4.74 / Benefit: 8.82 / C.Score: 4.08
(UAV2, JE1, UAV1, JE6, JE5, JE2, HE2, HE1, JE3)
Conclusions & On Going Work

We have proposed
- A reference architecture, **ITE Arbitrator**, to support local self-adaptation of individual participant systems as well as orchestration mechanisms across an entire IT ecosystem.
- A cost-benefit decision model in determining the optimal configuration in response to environmental changes; it also makes efforts to keep computational overhead at an acceptable level, even for scaling system configurations through applying genetic algorithms.

We are doing…
- Quantitative evaluations to show that the proposed **ITE Arbitrator** helps an IT ecosystem provide sustainable services.

We plan…
- To continue to self-evaluate as extend our framework to other domains of IT Ecosystems.
THANK YOU
Sustainability Enhancement

- Changes in the Global Collaboration Score

(a) Slow Weather Change/ Static Configuration

(b) Slow Weather Change/ Dynamic Reconfiguration

(c) Rapid Weather Change/ Static Configuration

(d) Rapid Weather Change/ Dynamic Reconfiguration

AVG: -1.09
AVG: 4.36
AVG: -3.33
AVG: 2.76
CASE: Unmanned Forest Management IT Ecosystem

(1) $HE2$ is assigned to $zone[0]/[2]$

(2) $HE2$ detects changed weather condition in $zone[0]/[2]$ and local adaptation cycle is invoked.

(3) A dynamic reconfiguration is invoked to assign a new participant to $zone[0]/[2]$ by running the global adaptation mechanism.

Optimal participant selection mechanism by applying genetic algorithm and cost-benefit model.