

Dynamic Multi-Layer Management of Service Based Systems in Hybrid Wireless Networks

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Abstract—The management of large scale service based systems hosted in dynamic environments of hybrid wireless networks is a complex task. Such systems are designed as composite services integrating heterogeneous service components such as sensor, software and data services. In this paper, we propose a new situational aware framework which allows the network operators to effectively manage such complex systems. The framework integrates three key components. The Service Placement component and the Configuration Service which collectively arrive at decision about placements and compositions of the services. An instrumental element of the framework is the Policy Based Management System providing the network operators with a tool to dynamically control these mechanisms.¹

I. INTRODUCTION

The essential management task of the service-based systems hosted in HWNs is to adapt to the changing conditions of the dynamic environment to maintain availability and functionality of the system components. This task is addressed by various methods such as dynamic service placement or dynamic service composition. Although the service-based systems are provisioned and used as a single functional unit, the existing methods are designed as independent functionalities addressing only specific aspects of management of the service-based systems such as dynamic composition of sensor services or dynamic placement of software services.

The complexity of the management of the service-based systems hosted in HWNs is further exaggerated by the various governing rules and policies constraining the systems runtime. For example in coalition operations, the system is constrained by the various rules limiting the use of services, resources or data provided and shared across the coalition partners. In such a complex environment, the system management methods must reflect in their decisions these rules and policies constraining the access and use of the various system resources and data.

In this paper, we propose a new situational aware framework which allows the network operators to effectively manage

such complex systems. Operators are considered components of the management system following the human-in-the-loop model. The framework integrates three key components into a single management tool. The Service Placement component, which dynamically optimizes placements of software services within the network reflecting the changing topology as well as the changing demand for the service functionalities. The Configuration Service component, which produces efficient composition graphs for invocation of sensor based services. The Service Placement and the Configuration Service components are integrated into a cohesive mechanism which collectively arrives at decision based on exchanging information about changes in placements and composition of the services. The third component is the Policy Based Management System (PBMS). An instrumental element that provides the system operators with a tool to dynamically monitor and control the placement and composition services' behaviour.

II. MOTIVATING SCENARIO

Consider for example the case of the management of a large-scale service based system, which supports decision makers operating in highly dynamic environments. Services in our scenario are application layer software components hosted and produced by hybrid, wireless network infrastructures. A hypothetical Service could be the monitoring of a suspicious vehicle, which might be composed of two sub-services; service S1: localization of the vehicle and service S2: tracking of its location. Sub-service S1 performs image recognition techniques on imagery data produced by a wireless, distributed CCTV system trying to localize the particular vehicle. Once the target has been localized sub-service S2 performs location tracking by assigning an unmanned aerial vehicle (UAV) to the vehicle. Each service produces one or more outputs and requires zero or more inputs from other services in order to perform in a hierarchical structure, forming workflow graphs for data processing. The Service Configuration component is in charge of this task. The Placement Service component optimizes placement of the services to ensure their optimal availability on the mobile nodes reflecting their current physical locations and network connectivity.

Moreover our scenario unfolds in a multi-partner environment. The services and the wireless network infrastructures

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that host and produce them are owned and operated by different collaborating partners. The PBMS component provides the system operators with a tool to express rule-based statements that enforce system’s behavioral and functional compliance. Through PBMS, operators also express and enforce security and privacy constraints that emerge due to the multi-partner dimension of the system. The policy based management component utilizing controlled natural language technologies, provides a user friendly policy interaction environment, facilitating the system’s management (policy authoring, policy conflict detection and resolution, policy negotiation), in particular for non-technical operators. A simple authorization policy rule on the aforementioned scenario where the owner of sub-service S1 is affiliated with partner P1 might be stating that he can only utilize imagery data produced by CCTV resources owned and operated by partner P1.

III. PROPOSED SYSTEM DESIGN

In the proposed framework, the “Placement Service” [1] and “Configuration Service” [2] collectively perform efficient placement and configuration of the services. The “Placement Service” positions services on network nodes while optimizing given network-level parameters, such as distance between nodes, bandwidth on links etc. The “Configuration Service” produces efficient composite services compliant with the hard constraints defined by policies and soft constraints such as geospatial relevancy to the area of interest of the user.

Utilizing bidirectional feedback mechanism between “Placement Service” and “Configuration Service”, the “Configuration Service” supplies composite service graphs (and thus topology) to the “Placement Service” which then migrates services in the network to optimize network level communication among nodes used in the composite service graph. The “Placement Service” receives the live monitoring data from underlying network probes and continuously determines optimal placement of services. Whenever it decides to move a service from one node to another node, such that the composite service graph is affected, it notifies the “Configuration Service” about the change. In response, the “Configuration Service” reconfigures the affected services according to updated service locations and network configuration. Figure 1 shows the feedback mechanism between the “Configuration Service”, “Placement Service” and “Dynamic Policy Engine” for efficient service management.

Note, that the frequency of service migration and service reconfiguration is highly situation dependent and that every service migration may or may not trigger a reconfiguration of services. This is because each service reconfiguration incurs certain cost and the gain from (new configuration according to) new service placement needs to be higher than the service reconfiguration cost in order to trigger reconfiguration. Similarly, every service reconfiguration may not trigger “service migration” because, if all services in a configuration graph are already well placed, they should not to be re-located. Moreover, the cost associated with service re-location also needs to be taken into account while triggering migration.

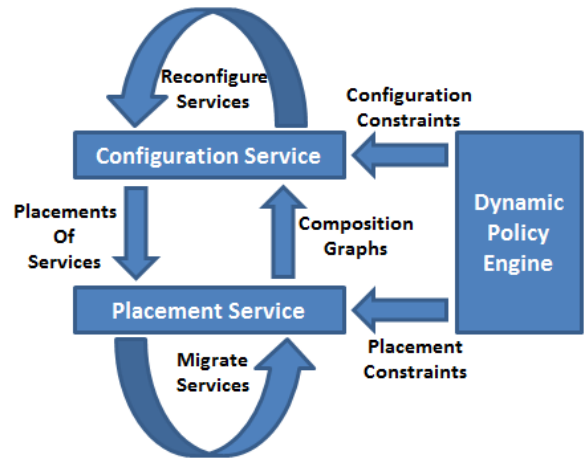


Fig. 1. Multi-layer Service Management with Human-in-the-loop

When the system starts, the two way communication between the two services happen for triggering “Placement Service” and “Configuration Service” in cycles till the system stabilizes to a desired level, after which actual services are instantiated.

The policy framework, as proposed by standards bodies [3] consists of four elements; a) policy management tool: to define the policies to be enforced, b) policy enforcement point (PEP): devices that can apply and execute policies, c) policy repository: to store the policies and d) policy decision point (PDP): responsible for interpreting the policies stored in the repository and communicating them to the PEP. Both, Placement and Configuration are high frequency and perpetual executed policy governed services. Given the fact that only a small subset of the policies that reside in policy repository governs their behavior, we propose a dual-level policy repository, which is composed of: a) the main repository and b) a smaller, faster accessed, level 0 repository which contains only these special purpose policies and operates tied to the aforementioned services.

IV. CONCLUSION

This paper, proposes a novel situational aware framework to address the complex management tasks of services-based systems operated in coalition environments. The collaborative work includes teams from Imperial College London (UK), Rensselaer Polytechnic Institute (USA), and Cardiff University (UK).

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