Opportunistic Collaborative Service Networks: The Facilitator for Efficient Data and Services Exchange

Dimosthenis Kyriazis, George Kousiouris, Alexandros Psychas(✉), Andreas Menychtas, and Theodora Varvarigou

National Technical University of Athens, Iroon Polytechniou 9, Athens, Greece
{dimos,gkousiou,alps,ameny}@mail.ntua.gr, dora@telecom.ntua.gr

Abstract. The dynamic rapidly changing and technology-rich digital environment and the market economic constraints shift service provisioning from a pre- and strictly-defined to an on-demand and ad-hoc orientation, where applications depend on dynamic, scarce, distributed resources, which operate at different temporal and spatial scales, have different (potentially conflicting) objectives and are governed under different domains of control. The framework described in this paper aims at enabling the exploitation of all available highly heterogeneous resources (i.e. clouds, communicating objects, sensors and smart devices) by providing a service-based environment that allows for harvesting, dynamically creating and managing these diverse, discrete and distributed resources. Swarms refer to opportunistic service networks, which as new constructs can rapidly emerge in relation either to users and applications requirements or to events and information of great potential for the wider community, coordinated by an open and distributed runtime model.

Keywords: Cloud · IoT · Sensors · Data exchange · Services exchange · Collaborative service networks · Opportunistic service networks · Swarms

1 Introduction

Trends for mobile device market penetration and cities going digital by deploying sensor infrastructures shape a rich and interactive digital environment. According to CISCO [1], during 2008, the number of things connected to the Internet exceeded the number of people on earth and by 2020 there will be 50 billion. Massive scale cloud infrastructures, sensors, intelligent fixed and mobile platforms (e.g. smartphones and tablets) and other network-enabled devices will all need to cooperate and interact to shift efficiency and create value across many sectors [2]. The challenge is for service-based environments to be the enabler for innovation and value creation by supporting the needs of dynamic Future Internet ecosystems and their collaboration models through the exploitation of a combination of technology trends and emerging compute models [3]. The aforementioned ecosystems will be developed and operated on top of the future computing continuum embracing clouds, communicating objects, sensors and smart devices, which will offer the corresponding assets (i.e. resources, services and

B. Mandler et al. (Eds.) IoT 360° 2015, Part I, LNICST 169, pp. 307–314, 2016.
DOI: 10.1007/978-3-319-47063-4_32

information) by collaborating towards realizing a common goal and providing a common user experience (as also depicted in Fig. 1).

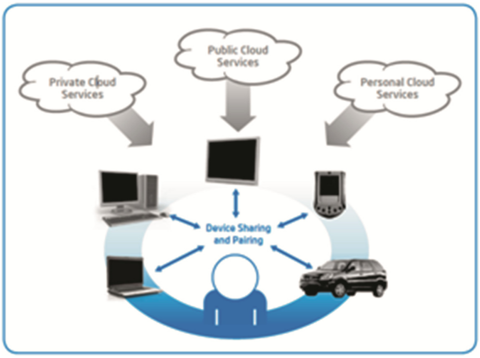

Fig. 1. Intel's view on the Compute Continuum [2]

However, the characteristics of these resources are significantly different to the commoditised and often "infinite" ICT assets offered by cloud infrastructures and some other service platforms today. Real-world resources are often scarce, distributed, governed under different domains of control and incentive schemes, providing unreliable services or information [4]. They are in very large numbers, which makes centralized approaches for their management inefficient [5], while their inherent characteristics and constraints need to be considered by platforms that aim to provide services on top of these resources. Of course it's the community and business structures and behaviours that will exert influence on the organisation of networks with the requirement that services and resources must become increasingly socially and dynamically distributed [6]. The overall goal is to allow for platforms supporting the very large (e.g. clouds) to coexist with platforms supporting the very small (e.g. mobile devices) in loosely coupled dynamic collaborative networks, which as new constructs can rapidly emerge in relation to users and applications requirements (e.g. data sharing in isolated localities such as aircrafts of ships) or when virtual or live events with massive potential generate information of interest for the community (e.g. picture of a football player celebrating a goal score, taken by a spectator sitting in the first row of a football stadium). Such networks can adapt automatically to changing environments, amplifying the collective ability and allowing for the provision of efficient solutions to difficult problems [7]. Nevertheless, their incubation in the Future Internet era faces several challenges.

The rest of the paper is structured as follows: Sect. 2 present the approach taken for the creation of the platform, in Sect. 3 the conceptual architecture is described. A real world application is presented in Sect. 4, while in Sect. 5 the research challenges and technological impact of the proposed approach are analysed. Finally Sect. 6 concludes the paper.

2 Approach

A swarm is a formulated and autonomous opportunistic collaborative service network which consists of voluntary heterogeneous sources that link dynamically and on the fly in order to provide assets (i.e. services, content and resources) to the application and the participants. Swarms are service networks deployed and executed in response to requirements, which may either emerge from application/user requests for services or information, or from opportunities offered in response to data- or event-driven activities. Swarm participants utilize the proposed platform, an open decentralized environment based on a distributed architecture model, in order to achieve the needed levels of logic (abstraction, discovery and participant selection, participation incentives, adaptation, runtime coordination, big data analytics, event identification and delivery patterns) that enable the swarm to perform its functional purpose.

The Platform builds on the notion of Collaborative Networked Organisations [8], which highlights that architecture and governance are influenced by the purpose of networked organisations (see image below Fig. 2).

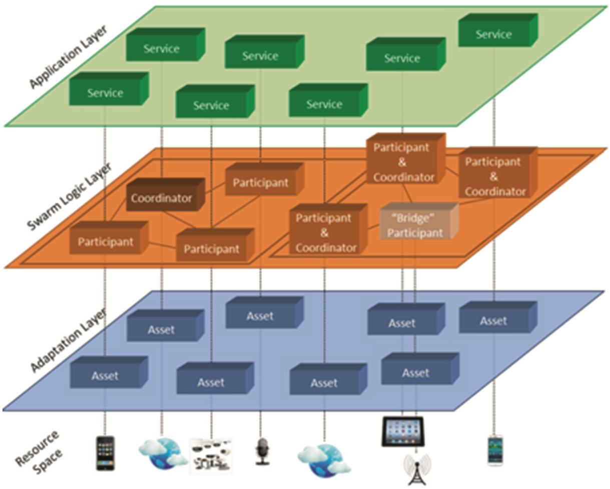

Fig. 2. Platform layers: From resources to collaborative networks

This is important as the platform deals with multiple and aggregated situations of sharing, contributing and co-creating. For "Sharing" a single entity would make assets available. This requires an architecture in which services cater for assets from the single source which may be passed on to many different recipients (services or end-users). For "Contributing" many different entities would make assets available to many recipients. The platform aggregates and collate content from many different sources to be used in many different ways. Ultimately, though, there is also a case where assets from many different sources come together deliberately to form a final, joint output that is "Co-Created".

3 Conceptual Architecture

The platform provides a system and mechanisms that enable the creation, deployment and execution of opportunistic service networks. The platform itself can be seen as a kind of decentralized middleware layer upon which applications are built. This middleware is what we call the swarm logic layer (as depicted in the following Figure) and it allows application service provisioning on top of multiple, diverse, distributed objects, sensors and smart devices. The adaptation layer allows for resources to be exploited both as information or service sources and as processing elements within a swarm. The swarm logic layer enables entities to participate in the service network, as well as management of the established swarm (including processes for monitoring, evaluation, runtime adaptation, etc.). Coordination may be either performed by a swarm entity (based on capacity, location or administration/trust criteria) or be distributed across the participants. Furthermore, participants may be included in swarms, acting as "bridges" so as to develop the required networking topologies that enable participants to be reached within the swarm.

The platform introduces an open advanced distributed runtime model that supports the complete swarm-oriented service lifecycle. Initially and given the available entities, there is a need to describe in a unified and abstract way the features, capabilities, characteristics and accession information of the devices. Moreover, the environment and the corresponding available assets are modelled and analysed with respect to application and system requirements and constraints as well as event and data triggers that may lead to swarm formulation. These requirements are linked to abstract system models described using dependability characterisations, which are used to assess impact in unknown and dynamic contexts for design and runtime operations. Models define the structure of the swarm, its constituting members (participants and relationships) and their roles as well as the swarm characteristics (e.g. location or time).

Furthermore, within this platform are also developed mechanisms that allow for the engagement of resources through approaches to identify, declare and manage different types of social, cultural and economic incentives with respect to service- and data-exchange, financial and collaboration aspirations. Following this process, potential swarm members are identified through real-world knowledge enriched services that allow resources to be discovered, filtered and reserved in a time-constrained way as required by the event- or opportunity- related requirements.

The platform also supports the operation of established swarms through mechanisms to control, influence, monitor and predict ad hoc interactions between swarm members. An open distributed runtime environment for decentralised management and coordination of multiple and diverse devices is developed to overcome inefficiencies of centralized management mechanisms given the number of devices, their locality and the fact that they are governed under different administrative rules and principles. Furthermore, runtime configurable swarm-oriented delivery patterns (e.g. building on top of a P2P concept) are instantiated given that centralized schemes (e.g. server-client) for service delivery is inefficient and in many cases insufficient (e.g. in a stadium with thousands of spectators). Delivery schemes/patterns refer both to the network topologies and communication channels within a swarm and are developed according to application requirements object capabilities and link characteristics. What is more, delivery schemes may affect the swarm formulation since inclusion of a participant as a proxy/bridge may be required to reach a resource. During operation, events are detected and analysed in real-time based on the information being exchanged, triggering actions with respect to resources (e.g. network bandwidth) and services (e.g. frame rate transition rate) provision. The platform provides methods to predict the likelihood of situations based on complex event processing to provide insight into new deployment strategies and the potential future impact of devices contributing to specific swarms (Fig. 3).

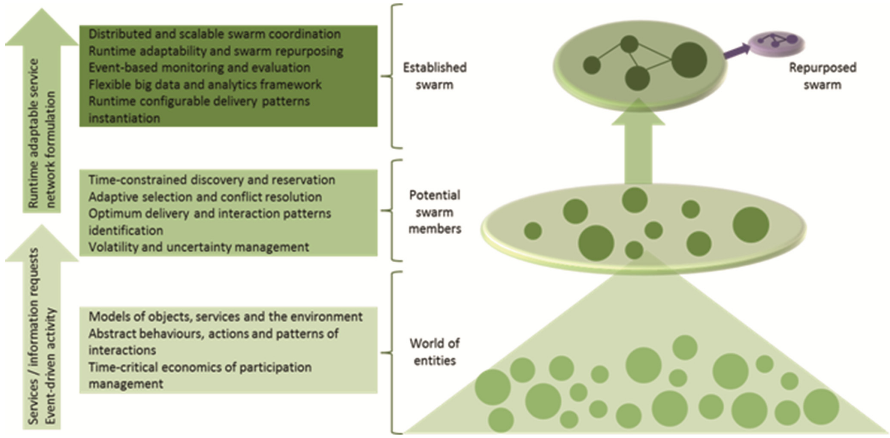

Fig. 3. The swarm formulation process

These tools aim at increasing situational awareness in real-time from information describing dynamic interacting objects based on modelling techniques that can predict the impact of performance and resource consumption under different conditions not known in advance. The platform also delivers mechanisms to handle the amount of structured and unstructured data considering both the location and administrative properties of the resources and the application requirements. Big Data solutions are applied in order to ensure both that the magnitude of data can be stored, retrieved and analysed in an efficient way, and that the object-related information can be utilized during the swarm formulation given that the amount of objects is in the range of millions and the swarm creation must be performed on the fly. Moreover, the techniques used aim at exploiting information out of the data in order to move only the necessary data over the network, thus minimizing redundant or unnecessary network traffic. Considering that valuable assets collected during operation as well as that established collaboration provided added-value, the platform provides mechanisms allowing for network repurposing in order to exploit these assets in new contexts and applications.

4 Applicability to Real World Use Case

This application explores novel ways of enhancing users' multimedia experience, flexible access to interactive and user-centric media and integration of virtual, mixed and augmented realities. The venue is a football stadium with basic IT equipment (e.g. wifi routers, Internet-connected servers, etc.). Furthermore, spectators in the stadium may capture information with their devices (e.g. smart-phones) or consume information and services provided by sources either in the stadium (e.g. infrastructure offering replays of goals scored) or outside the stadium (e.g. sports websites with commentary discussion and pictures from locations of interest, YouTube videos, etc.).

4.1 Scenario

It is Saturday in Spain and Primera Division (Spanish football league association) has scheduled 6 matches. A new service is offered (namely "*ShareYourView*") by La Liga, which some friends going to watch the match have downloaded from the Google Play website for their Android devices. The service aims to provide an enhanced experience of the event, both for spectators and attendees, enabling every spectator to have a "second screen" for watching the action, *ShareYourView* offers view sharing within the stadium as well as real-time data statistics overlaid on video streaming for the players. The following sections depicts a few typical examples of the *SmartStadium* application:

- Maria (one of the 2 friends) sitting on the north side of the stadium needs a camera view from the south side where the ball is in play and her friends are sitting (she could also obtain the video from other spectators but she does so from her friends since she has added them through the *ShareYourView* application). She opens the application and triggers the request.
- Anastasia (the second friend on the north side) holds a tablet and requests a higher resolution video which can only be offered by a limited number of spectators. Furthermore, Anastasia would like to get players' real-time information overlaid onto the video received from the other side of the stadium. While players' information is offered by the stadium cloud infrastructure, transcoding to enable the overlay cannot be performed in the same infrastructure but only in an external cloud environment.
- A penalty kick is awarded and a spectator sitting just behind the goalposts publishes through the *ShareYourView* application the possibility for others to see his view of the penalty kick. As viewers are now broadcasters, spectators will have access to amateur feeds that capture the authenticity of the live experience, rather than relying on what a director and cameraman focus on More than 10000 spectators express their interest in the specific view, while the view of the penalty kick is also requested by spectators in other locations (i.e. online, in stadiums of other matches). Moreover, advertised entities would like to see the impact of a promotion activity they put in place in all stadiums.

5 Research Challenges and Technological Impact

The proposed solution addresses several research and technical challenges as part of a service-based environment that aims to enable dynamic efficient and reliable service provisioning through the development of collaborative networks exploiting diverse, distributed, remote-located clouds, objects, sensors and devices. Specifically:

- *support opportunistic collaborations* through models of collaborative networks capturing dynamic multi-stakeholder requirements, collaborations classification including abstract behaviours, actions and patterns of interaction, and approaches to manage the economics of participation in order to engage resources, utilize spatial and societal attributes for service optimisation and take actions to encourage the likelihood of contribution to added-value service-based situations;
- *enable efficient and reliable service provision,* through ad-hoc collaborations realizing service networks with optimum delivery schemes and communication patterns to allow for information and service sharing and exchange, while managing uncertainty and creating reliability and dependability from volatile resources;
- *manage heterogeneous device platforms in a decentralized way,* through an event-driven autonomous/self-adaptive coordination of the devices following their role and participation scheme given that control is highly dispersed among the participating entities, and by adapting the collaborative network based on the evaluation of events impact and the anticipated service and information requests; and
- *incorporate scalable data and information management,* through techniques to analyse streaming data from various entities at real-time in order to obtain the potentially valuable knowledge from the information flows, approaches to manage the huge amount of data being generated by various sources, and workload optimized data stores that enable analytics to be performed in a scalable and efficient way (Fig. 4).

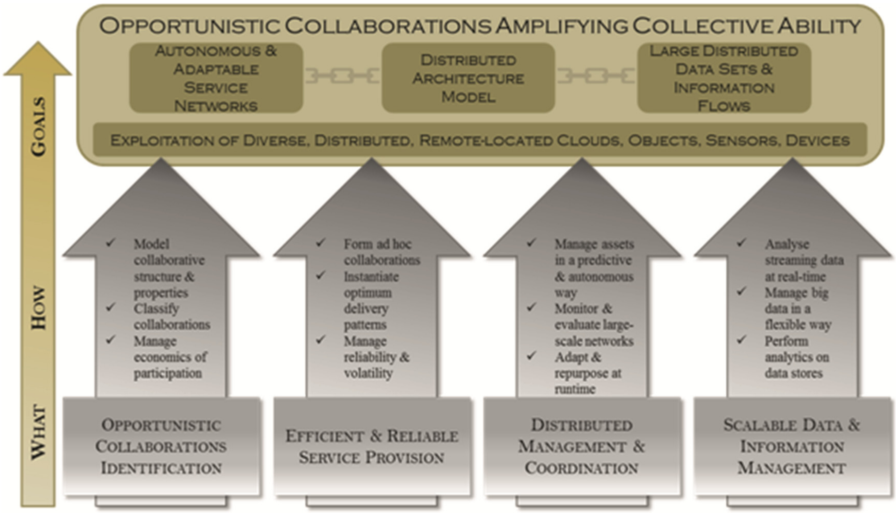

Fig. 4. Proposed approach challenges and impact

6 Conclusions

The dynamic rapidly changing and technology-rich digital environment and the market economic constraints shift service provisioning from a pre- and strictly-defined to an on-demand and ad-hoc orientation, where applications depend on dynamic, scarce, distributed resources, which operate at different temporal and spatial scales.

The presented vision aims at enabling the exploitation of all available highly heterogeneous resources (i.e. clouds, communicating objects, sensors and smart devices) by providing a service-based environment that allows for harvesting, dynamically creating and managing these diverse, discrete and distributed resources. Swarms refer to opportunistic service networks, which as new constructs can rapidly emerge in relation either to users and applications requirements or to events and information of great potential for the wider community, coordinated by an open and distributed runtime model. Time-constrained reservation, adaptive selection, conflict resolution and techniques to consider the volatility and uncertainty need to be developed to enable efficient and reliable service provision, harvest the vast availability of sensors and devices and lead to participatory application schemes of significant societal and economic value.

Acknowledgment. The research leading to these results is partially supported by the European Community's Seventh Framework Programme under grant agreement n609043, in the context of the COSMOS Project.

References

1. CISCO, The Internet of Things, Infographic. http://blogs.cisco.com/news/the-internet-of-things-infographic
2. IPSO Alliance, Smart objects power smart enterprises (2011)
3. Buchholz, D., Dunlop, J.: The Future of Enterprise Computing: Preparing for the Compute Continuum, IT@Intel White Paper, Intel IT (2011)
4. Gupta, A., Kumaraguru, P.: Credibility ranking of tweets during high impact events. In: ACM 1st Workshop on Privacy and Security in Online Social Media (2012)
5. Hofmann, M., Beaumont, L., Kaufmann, M.: Content Networking: Architecture, Protocols, and Practice (2005)
6. Barabási, A.L., Jeong, H., Neda, Z., Ravasz, E., Schubert, A., Vicsek, T.: Evolution of the social network of scientific collaborations. Elsevier Phys. A **311**, 590–641 (2002)
7. Bonabeau, E., Meyer, C.: Swarm intelligence: a whole new way to think about business. Harvard Bus. Rev. **79**, 106–114 (2001)
8. Dutton, W.H.: The wisdom of collaborative network organisations: capturing the value of networked individuals. Prometheus **26**(3), 211–230 (2008)