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-
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Abstract:

This addendum summarises the discussions that happened after the release of version 1.0 of the D.C.1 Deliverable. Thus, it clarifies the motivation and vision of OConS, highlights the key design principles, defines the networking concepts used, and presents the main building blocks. Moreover, it specifies a revised focus of the OConS work around two use-cases centred on the SAIL flash crowd scenario (rather than four as specified in D.A.1): OConS for CloNe – "Mobile access and data centre interconnect", and OConS for NetInf – "Mobile and Multi-P for information-centric networking". The experimentation and prototyping activities will be closely aligned with this refocused work.

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List of Abbreviations and Acronyms

BGP	Border Gateway Protocol
CloNe	Cloud Networking
CQI	Channel Quality Information
DE	Decision Making Entity
DNS	Domain Name System
DTN	Delay Tolerant Network, Disruption Tolerant Network
EE	Executing and Enforcement Entity
GTP	Generic Tunnelling Protocol
ICN	Information Centric Networking
ICST	Institute for Computer Sciences, Social Informatics and Telecommunications Engineering
IE	Information Management Entity
IEEE	Institute for Electrical and Electronics Engineering
IP	Internet Protocol
LTE	Long-Term Evolution
MPLS	Multi-Protocol Label Switching
MPLS-TE	MPLS support for Traffic Engineering
NetInf	Network of Information
OConS	Open Connectivity Services
OFDMA	Orthogonal Frequency Division Multiple Access
QoE	Quality of Experience
QoS	Quality of Service
SAIL	Scalable and Adaptive Internet soLutions
SAP	Service Access Point
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VPLS	Virtual Private LAN Services
WLAN	Wireless Local Area Network
3GPP	Third Generation Partnership Program

1 OConS Motivation and Vision

The goal of OConS is to provide enhanced and new connectivity mechanisms that are beneficial for the end-users and their applications, as well as for network operators. End-users enjoy better QoS or QoE with adapted connectivity, while network operators experience a more efficient usage of resources, higher throughput, and load balancing, which are collectively contributing to more satisfied users.

Future networks will need to rapidly adapt to the changes in traffic patterns. The driving forces behind those changes are the increased number and diversity of mobile devices connecting to the Internet, the variety of application requirements, the variety of communication technologies and networks, the dynamicity of social networks, and the flexibility at which new services and content are made available.

The proliferation of cloud computing appropriately supports social and media-oriented services, responding quickly to variations in the demand, e.g., by better distributing and managing media content, or by dynamically allocating more computing and storage resources upon a sudden surge in the demand. However, such dynamic on-demand behaviour is not adequately supported by the connectivity services of the current Internet and mobile systems, due to a variety of deficiencies at various levels, including physical/data link, routing and transport, and flow/session control.

Furthermore, current networking solutions lack efficient orchestration of several connectivity services spanning multiple protocols, layers and interfaces, and, as such, they demonstrate a relatively slow pace at which they adapt to the demand compared to, e.g., the speed of deploying virtual machines in data-centres.

In order to address these deficiencies and provide support to challenging SAIL scenarios, such as flash crowd community-oriented services exemplified in Deliverable D.A.1 [D.A.1], a novel approach is required. Thus, OConS provides agile connectivity services by providing the following features:

- Suitable mobile and wireless connectivity in challenged or over-crowded environments, using a combination of multiple technologies across multiple providers, thereby balancing the load among several paths and enabling access to content otherwise difficult to reach;
- Novel tailor-made, and possibly virtualised, connectivity services between the end-terminals, the involved accesses, the distributed cloud data-centres, and global inter-networking, quickly adapting to specific demands and providing an enhanced end-to-end QoS/QoE;
- The means (interfaces, services, protocols and algorithms) to orchestrate, manage, control and use these new connectivity services between the end-users and the community-oriented "gravity centres", efficiently utilising all available resources.

This is based on leveraging on what is working well in the current Internet and the latest mobile and wireless systems standards (e.g., 3GPP and IEEE technologies), and enhancing or replacing mechanisms and protocols when needed. The enhanced connectivity services are provided through an open connectivity framework, where existing and upcoming technologies and mechanisms remain inter-operable through well-defined interfaces. Furthermore, the approach is scalable and flexible, to ease the integration and activation of the proposed mechanisms, to better cope with the dynamics of networks and the continuous evolution of the technology. OConS services support security and privacy to the same extent as the current networks, preventing new flaws from being introduced by our enhancements, and maintaining the existing system and network resource integrity protection levels.

2 OConS Design Principles

The design of our connectivity services and the architectural framework complies with the following guidelines and principles:

- ***Build on the existing Internet foundations***: OConS builds on existing and proven mechanisms and protocols around the IP suite, such as UDP, TCP, DNS, BGP, or MPLS, only replacing or enhancing the outdated mechanisms/protocols (see, e.g., [FIArch11]) and assuring backward compatibility.
- ***Provide a unified and abstract access to the OConS services***: An application can explicitly express its requirements (e.g., QoS/QoE), which OConS translates into appropriate mechanisms from a given set of available ones, with appropriate policies depending on specific technologies, user, and operator preferences. Alternatively, without explicit signalling from the applications, OConS monitoring capabilities gain knowledge about the state of the network and the availability of OConS connectivity services, and invoke them as needed, in a manner that is transparent to the end-users.
- ***Provide an orchestration for the OConS***: Negotiate, choose and instantiate the OConS mechanisms to be used together with their appropriate policies (e.g., multi-path/multi-protocol selection and usage, dynamic mobility anchoring and execution, etc.); OConS mechanisms are as transparent as possible to OConS end-users.
- ***Support of different transport paradigms***: In OConS, as in the current Internet, different types of services require different types of transport mechanisms. OConS will reuse the connection-oriented or the connection-less mechanisms where appropriate: connection-less (UDP/IP), end-to-end best-effort connection-oriented (TCP/IP), connection-oriented approach with traffic engineering for edge-to-edge (e.g., MPLS or VPLS for pseudo-wires) or with QoS assurance for portions of the network where resource reservation is required (e.g., GTP for mobility management).
- ***Distributed and autonomous approaches*** will be exploited whenever possible for OConS management tasks.

3 Networking Concepts used by OConS

In this section, we present the novel networking concepts envisioned within the OConS framework, which are integrated with the inherited state-of-the-art solutions.

3.1 OConS Connectivity Services

OConS connectivity services are made from specific mechanisms that are instantiated on demand, and use a given policy and one or several protocol(s). They are specific to a given OConS domain; otherwise, inter-working is needed (see OConS domain concept). OConS connectivity services are grouped in the following three classes, as represented in Figure I:

- **Link Connectivity Services**: Link specific connectivity services, not spanning more than one-hop. They are typically implemented in the PHY or data-link layers. Examples of Link Connectivity Services from Deliverable D.C.1 [D.C.1], are: the *CQI Channel Allocation in the OFDMA* mechanism (Section 7.1.2), the *Wireless Mesh Link Connectivity Management* (Section 7.2.1), and the *Radio Resource Allocation for Virtual Connectivity* (Section 7.1.3).
- **Network Connectivity Services:** These are node specific services that are related to routing and transport mechanisms, being independent of the application. They involve two or more nodes, spanning over one or several hops (e.g., end-, access- or core-nodes).

Examples of Network Connectivity Services from [D.C.1], are: the *Routing and Forwarding Strategies for DTN* (Section 7.2.2), *Core-Network Routing and Data-Centre Interconnection* (Sections 5.2.1 to 5.2.3)

- **Flow Connectivity Services:** These are flow and session specific, either end-to-end or edge-to-edge, that are related to routing and transport mechanisms, and dependent of the application. Flow Connectivity Services from [D.C.1], include *Multi-Path transport* (Sections 5.2.4 and 5.2.5), *Multi-Path/Multi-Protocol Transport* (Sections 5.2.6 and 5.2.7), *Dynamic Per-Flow Mobility* (Sections 6.1.1 to 6.1.4), and *Transport Optimisations* (Section 5.1.2).

Resource Management can be seen as an underlying support function needed by OConS mechanisms. Some are specific for a given mechanism, enabling distributed resource management, whose coordination among several nodes is supported by control & management functions and by the mechanisms themselves. Also, certain management features are shared by several mechanisms and control & management functions.

Figure I depicts the OConS mechanisms and control-functions residing within a node (i.e., end-terminal or network-side node). A specific set of mechanisms and control-functions will participate to serve a given application request.

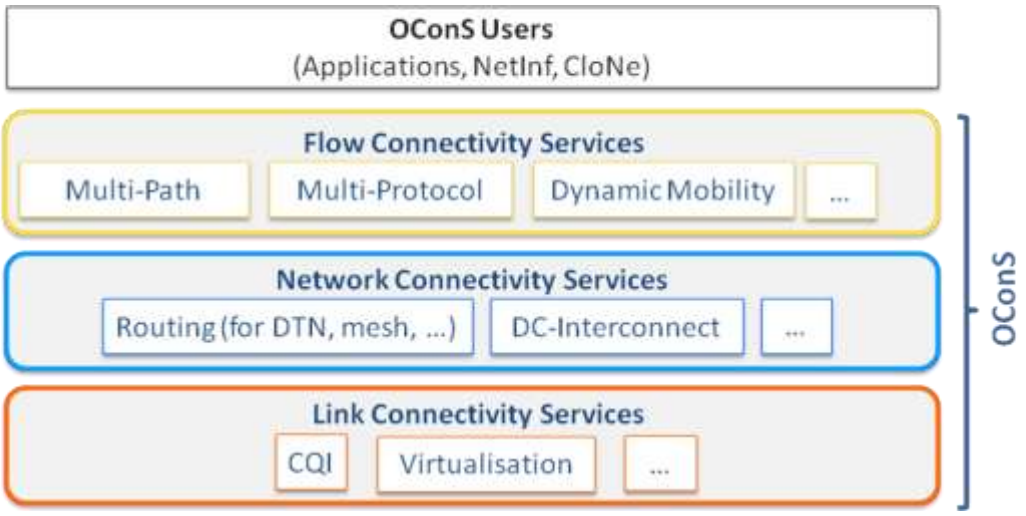

Figure I: Open Connectivity Services with related OConS mechanisms.

3.2 OConS Architectural Framework

We have proposed an architectural framework that supports the integration of innovative and legacy ***Connectivity Services*** responding to end-user connectivity requirements within a specific context. This framework defines a set of ***Functional Entities*** that separate the monitoring, decision making and enforcement components of any networking ***Mechanism***; this approach allows us to more easily implement, instantiate and launch a given connectivity mechanism, which may also be integrated with other OConS or legacy mechanisms to form OConS connectivity services at link, network and flow levels. Another key concept used within our framework is the ***Orchestration*** function that provides on-demand "connectivity-as-a-service". The orchestration function embeds the knowledge of the available networking resources of the ***Nodes*** and ***Links*** used within a given network, helping with node bootstrapping and discovery of local entities, thereby launching a specific set of OConS connectivity services to satisfy specific connectivity requirements from a given application. The elements that support this architectural framework are described in what follows.

Three ***OConS functional entities*** are defined as the building blocks of any OConS mechanism: the *Information Management Entity* (IE), responsible for information gathering and monitoring, the *Decision Making Entity* (DE), where the decision algorithms are implemented, and the *Execution and Enforcement Entity* (EE), which implements the decisions. These are the finest abstractions used in our framework, independent as much as possible from any layer or protocol. They are used for modelling/design purpose of all the proposed OConS mechanisms, thus, having a common way of representing our current and future mechanisms, and easing their instantiation, distribution and interconnection through clearly defined interfaces. Furthermore, the basic functional bricks facilitate sharing and reusability whenever possible (i.e., the information and measurements collection, the decision, and the execution entities). From the security viewpoint, the interactions between OConS functional entities are protected, so that the overall integrity of this process is ensured, namely, the interactions between the entities cannot be modified without being noticed; only trusted entities are authorised to participate in these interactions; reliable technical measures must be taken to allow the OConS entities to protect their interactions and be prepared to handle illegitimate modified interactions.

An ***OConS node*** is an infrastructure node (e.g., end-user terminals, base stations, routers, and switches) providing computing, storage and networking resources to the OConS entities (including virtualised resources). It is the place where the OConS entities are residing, instantiated, and executed, enabling the launch of OConS services. It can be a new node, or an existing one upgraded with OConS-related software. The nodes are to be associated to administrative domains, as the basic notion for ownership and the power to control security.

An ***OConS domain*** comprises a set of links and nodes, and provides connectivity services to the applications by implementing a given set of OConS mechanisms, (e.g., the support of Distributed Mobility Management, Multi-Path/Protocol, combination of these, and so on). An OConS domain can span several administrative (i.e., trust/management) domains. Inter-domain interworking (e.g., routing, transport) may re-use exiting mechanisms (such as BGP, IPX, etc.).

To serve an application/user connectivity request, the ***Orchestration*** functionality dynamically identifies the most appropriate OConS mechanisms from the set of those available. These can be distributed over several OConS nodes (e.g., end-terminals, access-routers, per-domain controllers, etc.), spanning one or several links or OConS domains. Thus, the orchestration applies at several levels, each level having specific orchestration purposes, see also Figure II:

- *Entities and Resources Orchestration*: orchestration among OConS entities, i.e., discovery/bootstrapping/configuration of OConS entities within a node, as well as the allocation and management of resources locally within a node.
- *Orchestration of Link, Network and Flow Connectivity Services*: negotiation and selection of the appropriate OConS mechanisms, and their instantiation and composition, within a single or multiple nodes, supported by specific OConS signalling. The service orchestration is triggered explicitly by the application, or implicitly by monitoring the network state.

These various orchestration functionalities, with their different scope and purposes, are further exemplified in Figure III. In the illustrated network model, an *Application* has specific requirements expressed to the orchestration *Service Access Point (SAP)*. Thus, the *Entities and Resources Orchestration* deals with a set of OConS entities, mechanisms and resources within a node.

Three *OConS service classes* are orchestrated as follows: the *Flow Connectivity Orchestration* activates a multi-protocol end-to-end transport service between Nodes 1 and 4; the *Network Connectivity Orchestration* launches a multi-path routing and transport service among Nodes 1, 2, 3 and 4; and the *Link Connectivity Orchestration* (not shown for simplicity) controls and manages the link specific OConS mechanisms, such as CQI channel allocation, mesh connectivity and wireless link virtualisation.

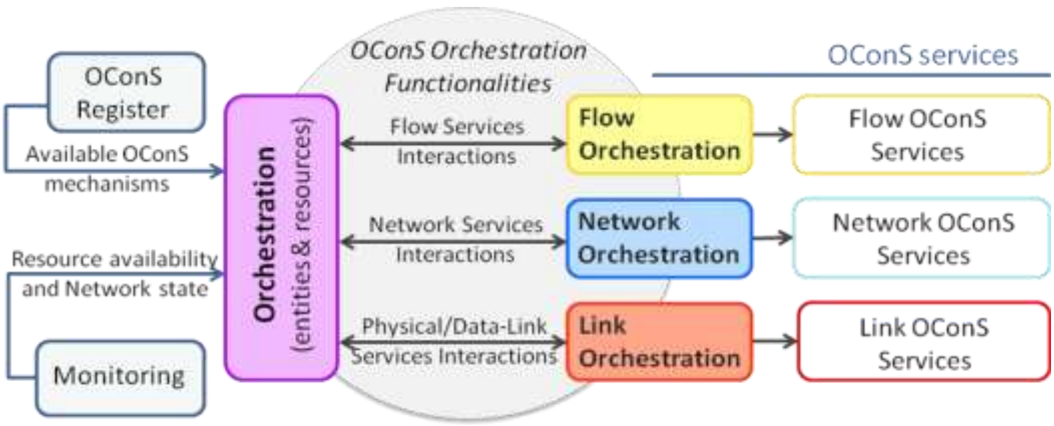

Figure II: OConS Orchestration Model.

OConS signalling (i.e., lightweight and flow-aware) between mechanisms and orchestration functions of the various nodes is exchanged, resulting in enhanced connectivity services that are made available for the applications. During operation, the orchestration functions monitor the proper operation of the entities, mechanisms and services, along with their interactions.

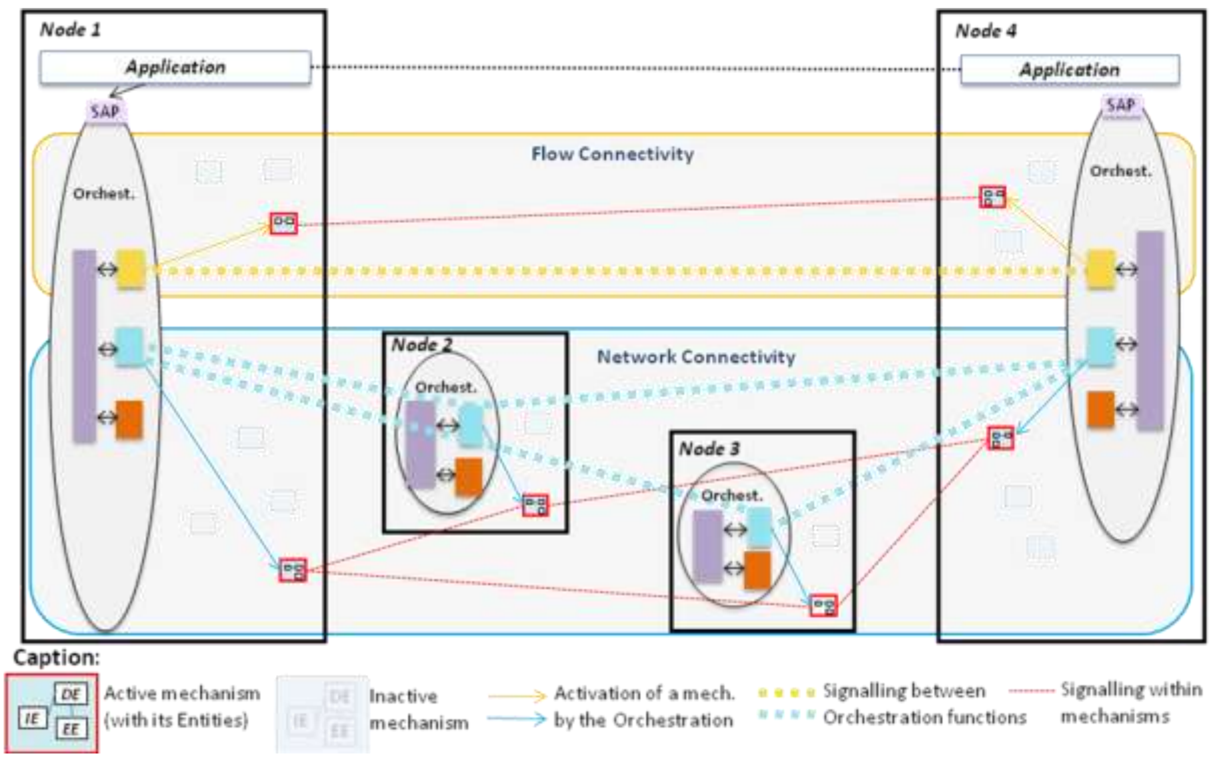

Figure III: Example of OConS network model, illustrating the orchestration functionality.

4 Deployment of OConS Building Blocks

This section addresses the flash-crowd scenario in the beginning, and then establishes a bridge between it and the work being developed in CloNe and NetInf.

4.1 Flash Crowd Scenario

The scope of OConS connectivity mechanisms range from access to core networks, from physical to network and applications, thus, OConS can be applied to improve ***S***calability and ***A***daptability of ***I***nternet **s**o***L***utions. All OConS mechanisms described in [D.C.1] can be orchestrated with each other to provide OConS connectivity. Some of them can be used alternatively or optionally, but due to their common architecture and interfaces, they can be orchestrated as required.

As examples of connectivity services to support innovative concepts, such as CloNe and NetInf, we focus on two use-cases related with these, within the overall SAIL flash crowd scenario as presented in [D.A.1]. Based on the requirements from CloNe/NetInf and available network resources, a combination of OConS mechanisms is proposed to improve connectivity, showing the deployment and instantiation of OConS entities, mechanisms and control functions[1].

In the flash crowd scenario, depicted in Figure IV, a large number of users concurrently and suddenly (e.g., due to a particular event) ask for connectivity and, in general, for network services, in the very same geographical region.

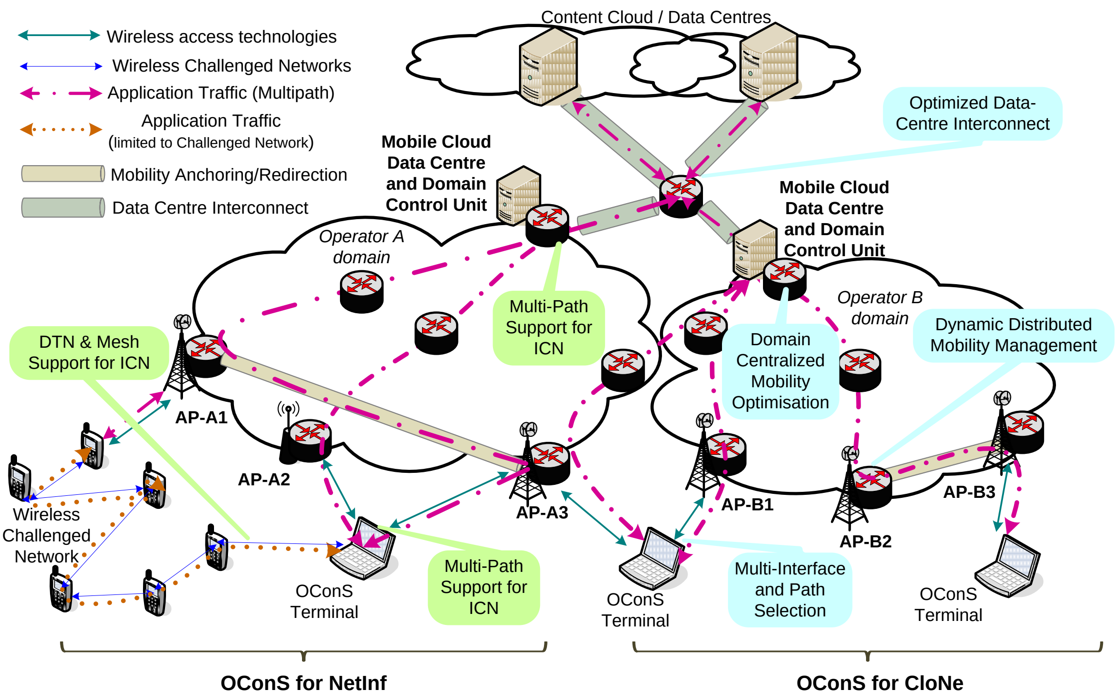

Figure IV: Flash Crowd scenario, illustrated with selected OConS services for two use-cases.

1 In this document we are providing descriptive text to show how the OConS approach works; the detailed orchestrations functions and the message sequence charts are to be provided in Deliverable D.C.2, due in July 2012.

Multiple network operators might be available in that area, each one deploying radio access networks with different technologies, e.g., 3G, LTE, WLAN, including mesh and relays. Moreover, users are equipped with different terminals, which, of course, are mobile, i.e., they may frequently change their point of attachment. Finally, users access different services, e.g., real-time services that download content, or upload on-spot generated data. Several OConS services can be therefore deployed on appropriate actors from this scenario to cope with the extreme dynamicity, to provide enhanced end-user experience, and to optimise network resource usage.

4.2 OConS for CloNe: Mobile Access and Data-Centre Interconnection Use-Case

This use-case specifically shows how OConS provides enhanced connectivity services for Cloud Networking (CloNe), for both enhanced wireless accesses (within a heterogeneous environment) and the core data-centre interconnection.

The ‘mobile flash crowd’ scenario is characterised by spatial and temporal distributions that are largely not predictable. The management solutions of this scenario require continuous monitoring, flexible interacting decisions, and enforced realisation of resource allocations, which exceed the capabilities of currently locally-acting autonomous mechanisms.

Furthermore, in this ‘mobile flash crowd’ use-case, we assume that there are resource short-comings at the wireless interfaces (due to overcrowded spectrum and mobility management entities), as well as at the access to popular community and content distribution services (represented by their ‘cloud gateways’ and data centres), which require a strict management of all available resources between both ends.

The OConS framework is applied to solve that challenge between different domains (wireless providers, content/social community providers) at different connectivity levels (wireless access vs. core connectivity), and in cooperation with CloNe management of cloud resources. In each of the involved domains, OConS information elements are used to monitor and collect information on available paths between clients and servers of their domain, as well as information on congestion of the network and path availability.

As soon as the flash crowd happens, the OConS framework has to react on the sudden increase of users requesting the very same “premium” content. Thus, the OConS framework can orchestrate appropriate OConS services. This is decided by the DEs (possibly hosted on a domain-specific OConS Control Unit), and enforced by the EEs implemented on servers, routers, switches, end-terminals. As depicted in Figure V, the orchestration of OConS services considers the following actions:

- Enable multi-path transport services on the servers in the data-centre, to leverage all the paths between clients and servers, in particular exploiting the least congested ones (Section 5.2.1 of [D.C.1]);
- Create new paths towards other instances of the same server, located in other data-centres, communicating with DEs possibly in other domains, via OConS signalling (Section 5.2.3 of [D.C.1]);
- Facilitate the handover of some users from congested to non-congested access networks, by interfacing with the DEs of the mobility management (Sections 6.1.1 to 6.1.4 of [D.C.1]), where different users will be handled depending on their capabilities and technology;
- Set policies in user-terminals with multiple interfaces, enabling the simultaneous use of two or more interfaces for load balancing purposes (Section 5.2.7 of [D.C.1])

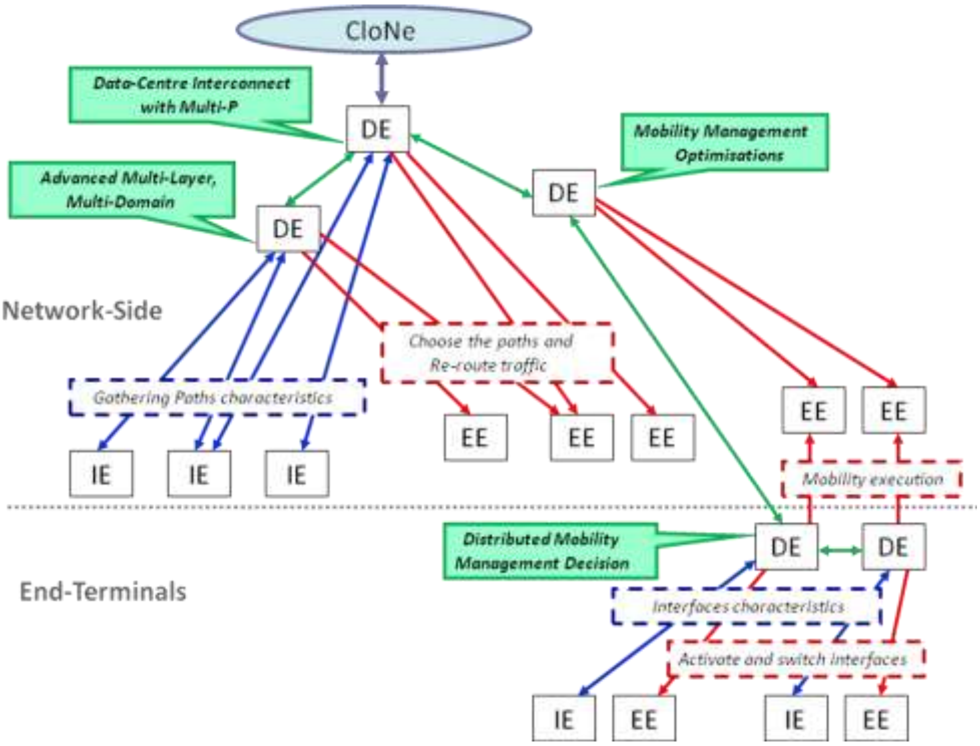

Figure V: Mobile Access and Data-Centre Interconnection use-case.

This example shows that coordination and execution of multiple OConS services can reduce the congestion in different access networks, and provide better QoE for the flash crowd users. Local replicas of the same server with improved connectivity can be made available to users, which can be seen as part of an overall 'cloud management' that interfaces with CloNE.

4.3 OConS for NetInf: Mobile and Multi-P for Information Centric Networks Use-Case

In this use-case, we illustrate how OConS provides connectivity services to Information Centric Networks (in particular to Network of Information – NetInf), creating and sustaining the connectivity in challenged wireless networks while using multi-path enhancements. We start with the assumption that there is a street performer and someone likes his/her performance very much, so he/she spreads the word through social networking, and a flash crowd is spontaneously gathered. Some people record and upload the event to a social network (e.g., Facebook), spread the word about the video around, and the flash crowd and other followers of the social network start to download the video, as well as background information about the artist.

The users employ NetInf nodes caching, and forward the produced content based on their name and locator. In this flash crowd, some users have good connectivity, while others experience poor or intermittent connections. OConS services can improve the connectivity of the flash crowd users, which require a minimum reliability, a minimum QoE, and therefore, require optimised resource utilisation. More specifically, the message forwarding functionality in each NetInf node needs to be enhanced by OConS. Thus, by collecting network information via OConS IEs, the DE in the OConS enhanced NetInf message forwarding function can decide to activate and configure OConS mechanisms using the appropriate EEs.

In this use case, the following OConS functions are considered, Figure VI:

- OConS multipath connectivity services (Section 5.2.4 of [D.C.1]) can select the best multipath strategy (distribution, splitting, and replication) to retrieve content to the mobile devices. The selection and enforcement of these strategies are performed at the participant devices as well as in the network.

- For poorly or temporarily disconnected users, OConS DTN routing (Section 7.2.2 of [D.C.1]), OConS Mesh Networking (Section 7.2.1 of [D.C.1]), optimised CQI channel allocation (Section 7.1.2 of [D.C.1]), and OConS Network Coding (Section 5.1.2 of [D.C.1]) can further improve the NetInf nodes connectivity.

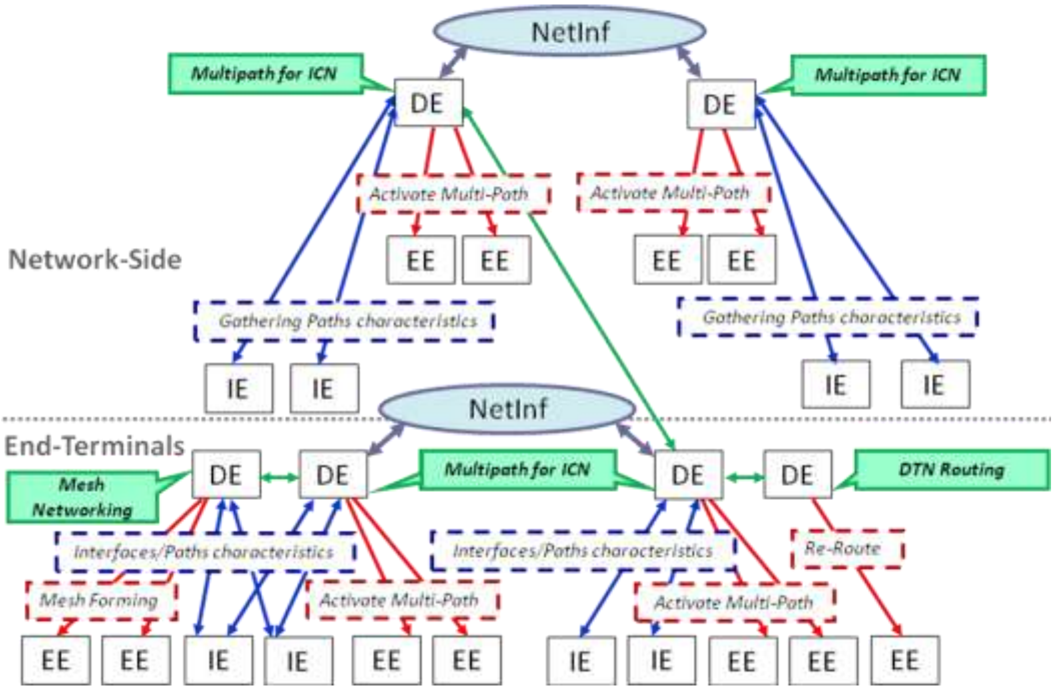

Figure VI: Mobile and Multi-P for Information Centric Networks use-case.

5 Evaluation with respect to Design Principles and Architectural Guidelines

OConS provides a generic framework that is used to orchestrate and launch different advanced connectivity services, according to the context of the instantiated services, the applications needs, and the corresponding network conditions. Rather than providing a monolithic design that is typically restricted to the initial set of requirements, we advocate the use of an open approach; this will allow us to better cope with the continuous and rapid evolutions of the connectivity patterns, beyond what is foreseen nowadays while supporting forthcoming communication scenarios.

The OConS framework has been designed to be self-adaptive, while demonstrating an autonomous operation, and centralising only the functions that cannot be distributed without impacting the overall optimisation. This implies that the orchestration entities will take the most appropriate actions, i.e., instancing different modules, procedures and algorithms, as well as combinations of them. We argue that this will lead to a better behaviour than the currently available approaches: in many of the current cases, where these solutions are working in isolation, the corresponding decisions might be incompatible or contradictory, and the finally adopted ones are likely to be suboptimal. In addition, by being able to tailor the joint-operation of several connectivity services independently at each network region, the OConS approach would be able to adapt more quickly to the varying networking conditions without requiring drastic reconfigurations and/or the reestablishment of communications.

In order to bring about those functionalities, OConS relies on a simple and generic architecture, which can be adapted to different types of connectivity and services' needs. The previous section exemplified the flexibility of the OConS framework and its unique ability to adapt to rather distinct communication scenarios and technologies.

6 Refocusing WP-C

In the remainder of the project, WP-C will bring to conclusion the research and evaluation of each individual connectivity service presented in [D.C.1]. In addition, our re-focussed work will be directed to the following items.

- The assessment, specification and design of the OConS orchestration functionality. More effort will be directed to interconnect specific OConS mechanisms through appropriate orchestration, resulting in a future-proof OConS framework, flexible and ease to evolve.
- Tighter integration of OConS services into the overall SAIL project, supporting CloNe and NetInf scenarios with appropriate services; instead of four use-cases originally considered in Chapter 8 of [D.C.1], we integrate the proposed OConS mechanisms into two use-cases: Mobile Access and Data-Centre Interconnection (for CloNe, see Section 4.1) and Mobile and Multi-P for Information Centric Networks (for NetInf, see Section 4.2).
- OConS principles and services have been demonstrated through selected prototypes such as: "Dynamic and Distributed Mobility Management with OConS", "OConS Flow-Based Domain Connectivity Control", "Using OpenFlow to Interconnect Data Centre", "OConS multi-path support for NetInf"; in the coming months WP-C will integrate two demonstrators on this basis, one supporting CloNe and one NetInf, as planned in Deliverable D.C.3.

D.C.2 will include the final mechanisms, the orchestration of these mechanisms, the common supporting functions (e.g., discovery/negotiation) and the fully defined OConS internal and external interfaces. By capitalising on some of the concepts from 4WARD Generic Path (such as cross-layer optimisation, node compartments, and service orchestration) [4WARD09], [4WARD10], we will support the most appropriate flow, network and link connectivity services with open interfaces among the OConS entities.

Then, in D.C.4 we will present the applications for the open connectivity services (such as CloNe and NetInf), provide the technical results, and evaluate them.

Furthermore, the results of this work will be also disseminated and demonstrated:

- At the SAIL summer school, with a comprehensive tutorial on the OConS services and how they can be used by future applications and concepts like ICN;
- At a workshop on Resource Management for OConS services organised by OConS planned during the ICST MONAMI Conference in Hamburg in September 2012;
- With OConS demonstrators in Q3 2012, including several partner contributions supporting CloNe and NetInf and demonstrating the OConS service orchestration.

7 Conclusions

Since the release of Version 1.0 of Deliverable D.C.1 (presenting the first draft of the architectural concepts of OConS), and after the external reviewers' feedback, the work within OConS has been clarified and refocused, as synthesised in the current document. The final OConS architecture will be presented in Deliverable D.C.2 due in July 2012.

The OConS motivation and vision is to provide enhanced and new connectivity mechanisms that improve end-users experience and operators' network performance, by providing adaptive, flexible, heterogeneous, and multi-protocol solutions to better cope with the dynamics of networks and the continuous evolution of technology. The connectivity services and architectural framework build on the existing Internet foundations, support different transport paradigms, and provide a unified and abstract access to connectivity services, on-demand, based on the proposed orchestration functionalities.

The networking concepts used (i.e., entities, services, nodes, domains) have been clarified, and the orchestration functionalities needed to launch and combine OConS services have been investigated in depth. Accordingly, OConS services were divided into three main classes, following their main characteristics and abstractions they apply to, as follows: Link Connectivity Services, Network Connectivity Services, and Flow Connectivity Services, respectively. These services are orchestrated on-demand using the OConS-related signalling as specified by the OConS framework.

Furthermore, to harmonise our research and to better integrate our work into the overall SAIL approach, within the overall SAIL flash crowd scenario as presented in Deliverable D.A.1, our work has been refocused around two main use-cases ("Mobile access and data centre interconnect" and "Mobile and Multi-P for information-centric networking"), aiming at providing connectivity and supporting the innovative concepts of Cloud Networking (CloNe) and Network of Information (NetInf). Likewise, the prototyping activities will be also aligned with these use-cases.

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