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Towards Autonomic Management of Software Enabled Networks

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***Abstract*- In this position paper, we present a new networking and management framework – called SeNET - that integrates software driven features with the management features of modern autonomic network management, and many service features from the world of services. This framework is under development and validation.**

***Keywords*: Software Driven Networking, Programmable Networks, Autonomic Networking and Management**

I. INTRODUCTION - SOFTWARE ENABLED NETWORKS (SENET) AS FUTURE NETWORKS

The rapid and continuous evolution of network technology and changing user requirements drives the research community to explore new concepts and paradigms that need to be addressed in the following 5-10 years. The final goal of the research is to devise a flexible, scalable, and robust end-to-end smart integrated network, which addresses the requirements coming from both users and operators, and is able to cope with the constraints imposed by both fixed and wireless access infrastructures.

Our approach to this challenge is through programmable network infrastructures that support software driven features, which can be instantiated on-demand, based on the changing requirements and resource constraints. Software Driven/Enabled Networking design goals, would include: network Programmability and Elasticity [2][7]; Integrated Virtualisation of Connectivity, Storage and Processing Resources, including the limited resources in smart objects [6] [12], In-Network Management 'SeNET as a Service' [1].

A non-exhaustive list of such features is described below.

• Interworking – SeNETs are represented by the inter-connection and inter-operation of several heterogeneous and dynamic networks sharing their virtualized resources. Resources such as processing, storage, and communication resources of multiple domains and networks would be made available to for aggregation to support provision of any service in a pervasive manner [8][9][10].

• Service Access – SeNETs should offer permissive access to different service providers: SeNETs should provide to service providers qualified access mechanisms to a set of network embedded resource-facing services, providing scalable, self-managed inexpensive networking infrastructures on demand [5].

• Service Provisioning – SeNETs can provide services of any complexity: Future Networks should support the complete lifecycle of services that can be primarily constructed by combining existing elements, in new and creative ways, that often were not efficiently inter-operable before [3][4].

• Network Empowerment characteristics are: Service-, Content-, Knowledge-, Environmental-, Energy-, Economic - and Social- awareness [6] [12].

The fundamental difference between SeNET and Next Generation Networks (NGN) is the switch from 'packet-based' systems such as those using the Internet Protocol (IP) with a separate transport and service strata in NGN to a packet-based network with service and management-aware characteristics, which is based on shared virtualized resources in form of processing, storage and communication resources, reaching even to the resources of the resource-constrained smart objects. These features of SeNET are shown in Figure 1.

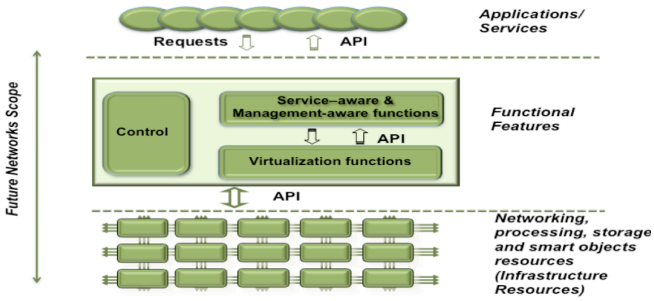

Fig. 1. Key Features in SeNET

II. SENET CONTROL & MANAGEMENT INFRASTRUCTURE

The following figure 2 presents the blueprint on the SeNET control and management infrastructure where the main functional blocks are as follows:

• *Operator Control* is responsible for the privileged control of the operators, who own the physical infrastructure.

• *Network Application and Service Control* is responsible for the management and the dynamic mapping of the service ecosystems to the virtual resources.

• *Virtual Network Control* is responsible for the dynamic setting-up and management of the unified virtual networks unifying the virtualisation of connectivity, computation and storage resources.

• *Virtual Resource Control* is responsible for the management and the dynamic mapping of the virtual resources to the heterogeneous physical resources.

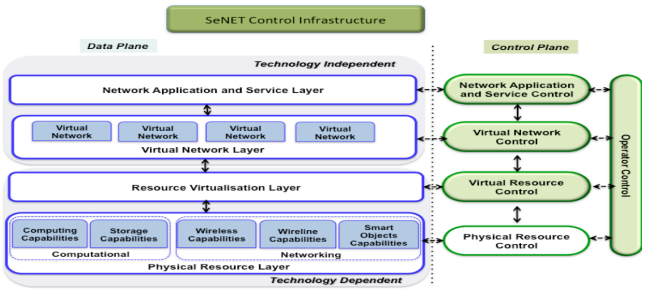

Fig. 2. Blueprint of SeNET Control & Management

III. SeNET Characteristics

The Software Enabled Network architecture is associated with the following characteristics and challenges:

- Unification and higher degree of virtualisation for all infrastructure systems: virtualisation of services, networks, storage, content, and resources as the means of enabling change from capacity concerns towards increased and flexible capability with operation control.
- Software driven features: network programmability and elasticity; integrated virtualisation of connectivity, storage and processing resources, including scarce resources in smart-objects; In-bound Management.
- New integration concepts enabling better integration and usage of the communication-centric, information-centric, resource-centric, content–centric, service/computation-centric, context-centric, management-centric faces.
- New virtual infrastructures addressing the unification and integration of connectivity, computation, storage and control resources.
- In-bound manageability: Embedded autonomic management in systems, elements and operations.
- Full network empowerment including Service- , Content- , Knowledge- , Environmental- , Energy- , Economic- and Social- awareness.
- Address explicitly a number of design requirements including: openness, economic viability, fairness, scalability, manageability, evolvability and programmability, autonomicity, mobility, ubiquitous access and usage, security including trust and privacy, large-scale heterogeneous systems integration and deployment.

IV. SeNET Control & Management TestBed

We are developing at UCL an early implementation of an SeNET infrastructure to verify the design and architecture. This development is a small software-based service and network testbed - the Very Lightweight Software Driven Network and Services (VLSP) in Figure 3, which comprises a very lightweight virtual router element combined with virtual network connectivity. These elements can be combined in order to build any network topology required. The created virtual network is designed with the goal of transmitting and routing datagrams from any source to any destination. It behaves like a lightweight virtual datagram network, but it has management facilities to start and stop virtual routers on-the-fly, together with the ability to create and destroy network connections between virtual routers dynamically. Furthermore, these lightweight routers have an application layer interface that provides the capability to start and stop Java software applications. It was tested with a topology of 700 virtual nodes. Figure 3 shows how the elements of the VLSP map onto the SeNET.

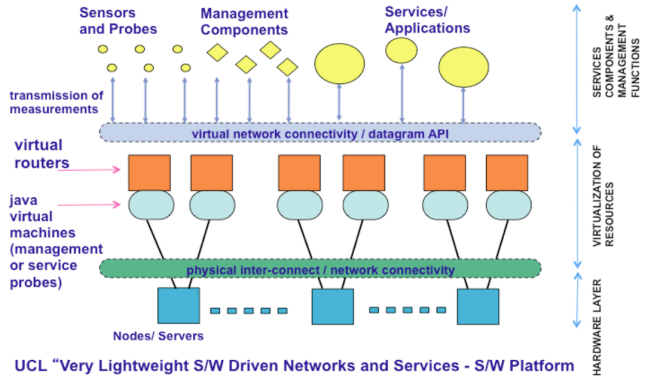

Fig. 3. UCL "Very Lightweight S/W Driven Networks"

V. SeNET TestBed Demonstrations

We demonstrate an SeNet infrastructure providing basic communication services over dynamic topologies and embedded network management operations self-optimizing the communication flow. Novel management abstractions as well as sophisticated mechanisms and algorithms are tackling the communication flow optimization problem from both top-down and bottom-up viewpoints. The management abstractions follow the Universal Management Framework (UMF) specifications [1]. The UMF is an innovative management framework that aims to solve challenging network problems and address the growing management complexity of the highly decentralized and dynamic environment of resources and systems in the Future Internet. The Network Empowerment Mechanisms (NEMs) [1], encapsulate autonomic functions (closed control loops/algorithms) that can be embedded into legacy and future networking systems and services in a “plug-and-play” / ”unplug-and-play” way.

In this demonstration, we involve two intelligent management components (i.e., NEMs) we use: the Virtual Infrastructure Management (VIM) and the Placement Optimization (PO) NEMs. The VIM NEM manages the virtual infrastructure through providing management/control functions, such as virtual topologies/paths establishment, traffic monitoring and deployment of nodes providing network services (e.g., aggregation points). Basic VIM functions and algorithms are elaborated in [10], [11]. The PO NEM optimizes the data flow through adapting the position of the communicating nodes in response to the dynamic network conditions (i.e., real-time topology and traffic status). It uses novel placement algorithms (i.e., the Pressure and PressureTime algorithms) that were extensively validated (theoretically and experimentally) in papers [9], [10].

The demo run involves the core service that provides intelligent information / knowledge handling abstractions in the UMF. The basic interactions between the VIM, PO NEMs and the core service are shown in Figure 4. The VIM NEM starts publishing real-time network monitoring information (i.e., the link loads and topology information) - the topology

changes very frequently (i.e., grows every few seconds). The PO NEM subscribes to be notified whenever link load is above a specific threshold. This triggers redeployment of communication nodes (i.e., information aggregation points, in our example) in order to reduce the communication overhead.

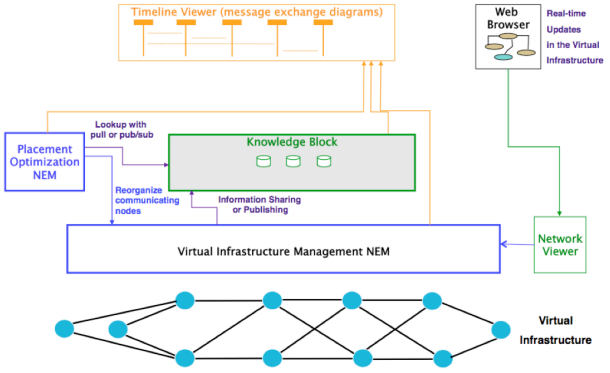

Fig. 4. Basic demo components, the virtual infrastructure and the visualization tools

As we show in Figure 4, we visualize the updates in the dynamic topology / communication node placement, the message-exchange diagrams for all interactions and the behaviour of the VIM and PO NEMs, including real-time monitoring information and topology status as well as the behaviour of the internal core service functions.

Our SeNET implementation is a software-based service and network test-bed, which was tested with a topology of 700 virtual nodes. We implemented from the scratch all the required components, including the virtual routers (i.e., more than 100000 lines of code).

ACKNOWLEDGMENT

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