Telecommunication Networks and integrated Services (TNS) Laboratory

Department of Digital Systems
University of Piraeus Research Center (UPRC)
University of Piraeus

Laboratory Profile

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Outline

- **Profile (brief)**
  - Institution, department, laboratory

- **Past and ongoing research activities**
  - Emerging assets - Ongoing research activities
  - Legacy assets - Completed research activities

- **Future interests regarding research activities**
  - Evolution of ICT infrastructures and services
  - ICT and energy, transportation, environment management, sustainable growth, Internet-connected social vehicles

- **Concluding remarks**
- The University of Piraeus comprises nine academic departments

- The University of Piraeus Research Center (UPRC) provides administrative assistance to basic and applied research activities, conducted by the personnel of the University of Piraeus

- The Department of Digital Systems was founded in 1999
Profile [2|8]: Laboratory

- **Telecommunication Networks and integrated Services (TNS) Laboratory**

- **Objective - Short Description**
  - The Laboratory of Telecommunication Networks and integrated Services (TNS) is framed within the Department of Digital Systems, of the University of Piraeus.
  - The main objective of the TNS Laboratory is to conduct research and development in all areas related to telecommunication networks and services. Through its research, development and educational activities, the Laboratory will contribute to the realization and sustainable development of a human-centric Information and Communication Society.

- **Personnel**
  - 3 members of faculty
  - 4 Senior Research Engineers (PhD)
  - 5 Research Engineers - PhD students
  - 25 Research/Software Engineers - Thesis at postgraduate or undergraduate level
The TNS Laboratory conducts applied and basic research on:

- Wireless and mobile broadband communications
  - Heterogeneous networks, small cell networks, cloud-based radio access networks
  - Spectrum management (licensed, shared, unlicensed), radio resource management
  - Device-to-device networks, opportunistic networks, cognitive radio networks
- High-speed, fixed-access and core networks
- Internet and Web technologies
- Internet of Things, Future Internet
- Cloud platforms
- Energy-efficient infrastructures
- Network management (platforms, algorithms), design, performance evaluation
  - Autonemics, cognitive networks
  - Software-defined networking (SDN), network function virtualization (NFV)
- Smart grids, smart cities, environment, critical infrastructures, transportation
- Optimisation, algorithms and complexity, queuing theory, machine learning
- Standards
Profile [4|8]: Emerging and legacy assets

- Services for a sustainable, inclusive, prosperous Society
  - Smart cities, environment management, digital enterprise
  - Legacy: IMPULSE, WIN-HPN, MONTAGE, SCREEN, Moebius

- Big data platforms, Machine learning mechanisms
  - Emerging: UniverSelf
  - Legacy: E3

  - Management of ICT Infrastructures
    - Emerging: UniverSelf, Auto-Flow
    - Legacy: ENISA, E3, STORMS, SHUFFLE, CREDO, MONASIDRE

  - Cloud - IoT Platforms
    - Emerging: iCore

  - Smart Wireless Access
    - Emerging: Auto-SDN, ARTEMIS
    - Legacy: MCAPs, OneFIT, E2R I & II, ACROPOLIS, COST Action IC0902, ACE, ARIADNE

  - Device Management
    - Legacy: INTEL Collaboration
Profile [5|8]: Emerging assets

Contributions to EU-funded projects and initiatives

- FP7/ICT UniverSelf (Self-management in the FI) - IP - WP leadership
- FP7/ICT iCore (Internet Connected Objects for Reconfigurable Eco-systems) - IP
- Greece - China bilateral collaboration project ARTEMIS (Cognitive ecosystem for energy efficiency)
- AutoSDN (Autonomics and Software Defined Networking: Instantiation to LTE SON)
- AutoFlow (Geant) (Autonomic OpenFlow)
- FP7/ICT ACROPOLIS (Advanced coexistence technologies for Radio Optimisation in Licensed and Unlicensed Spectrum) - NoE
- COST ICT Action IC0902 on Cognitive radio and networking for cooperative coexistence of heterogeneous wireless networks - National representative
Profile [6|8]: Legacy assets

TNS Research, Standardization Activities: Infrastructure

- **FP7/ICT OneFIT (Opportunistic networks and Cognitive Management Systems for Efficient Application Provision in the Future Internet)**
  - Networking schemes for wireless access to the Future Internet (Project coordination)
- **MCAPs**
  - Strategies for Creating Networks of Moving Cognitive Access Points
- **FP7/ICT E³ (End-to-End Efficiency)**
  - Cognitive networks and systems (Technical Management)
- **ENISA**
  - Ontology for modelling resilience stakeholders and associated concepts
- Experimentation platform for the assessment of an IEEE 1900.4-based management architecture
- **FP6/IST E²R (End-to-End Reconfigurability)**
  - B3G Infrastructures, Reconfigurable, Software Adaptable, SDR
- **FP6/IST ACE (Antenna Centre of Excellence)**
  - 4G systems
- **FP5/IST MONASIDRE, CREDO, SHUFFLE**
  - B3G Infrastructures, Cooperative
- **FP4/IST STORMS**
  - Design of 3G Infrastructures
- **ARIADNE (Ministry of Development, General Secretariat for Research and Technology):**
- **Consultancy (Ministry of Finance, Ministry of Education, Private sector related to 4G systems and WiMAX)**
Profile [7|8]: Legacy assets

**TNS Research, Standardization Activities: Services**

- **INTEL Collaboration**
  - Platform development: Quality of Experience enhancement, lower costs and green decisions
- **EUREKA/CELTIC IMPULSE (Integrated Multimodal Platform for Ubiquitous Multimedia Service Execution)**
  - IMS platforms
- **EUREKA/CELTIC WIN-HPN (Wireless Intelligent Hospital Premises Network)**
  - Digital Health
- **FP5/IST**
  - Moebius
  - E-Business and Digital Health over 2.5G and 3G Infrastructures
- **FP4/IST**
  - Screen, Montage
  - Service Engineering, Accounting, Personal Mobility
- **DIOSKOUROI**
  - Training and consultancy on modern telecommunication infrastructures and services for Military personnel
Active participation to standardization bodies, research fora and organisations

- ETSI-RRS (Reconfigurable Radio Systems)
- AFI (Autonomic network engineering for the self-managing Future Internet)
- Future Internet Initiatives
- Wireless World Research Forum (WWRF) (2004 – today)
- European Networks of Living Labs (ENoLL) (2011 – today)
- Cognitive Communications WUN (2010 – today)
- TM Forum (2012 – today)
- GreenTouch (2012 – today)
- Next Generation Mobile Networks (NGMN) (2012 – today)
Research Achievements/ Portfolio

**Smart Wireless Access**
- **AutoSDN**: Autonomic Software Defined Networks (collaboration with Orange); 2013-2014
- **ARTEMIS**: A cognitive ecosystem for smART Energy Management of wireless technologies and mobile applications (Greece-China collaboration); 2013-2015
- **OneFIT**: Opportunistic networks and cognitive management systems for the Future Internet (project management); 2010-2012,
- **Acropolis**: Advanced coexistence technologies for Radio Optimization in Licensed and Unlicensed Spectrum; 2010-2013
- **COST**: ICT Action IC0902 (national representative); 2010-2013
- **MCAPs**: Moving Cognitive Access Points (U.S. Office Naval Research); 2012-2013

**Management of ICT Infrastructures**
- **AutoFlow**: Autonomic OpenFlow (funded by GEANT); 2013-2015
- **UniverSelf**: Autonomics for the Future Internet; 2010-2013
- **ENISA**: Ontology and taxonomies for resilience; 2011
- **E³**: End-to-End Efficiency, cognitive management in the wireless world (technical management); 2008-2009

**HetNets**

**Opportunistic Networking-D2D/M2M**

**Bands**

**Device Management**
- International point-to-point collaborations with Intel: 2010-today

**Services for a sustainable, inclusive, prosperous Society**

**Big data platforms, Machine learning mechanisms**
- UniverSelf
- E³

**Cloud – IoT Platforms**
- **iCore**: Internet Connected Objects for Reconfigurable Ecosystems; 2011-2014

**Specialties**
- Broadband Networks; Future Internet; 5G Wireless;
- Smart Grids, Smart Cities, Environment and Critical Infrastructures Management;
- Virtualization, SDN;
- Standards
Emerging assets: Management of ICT Infrastructures: UniverSelf: Autonomic management of FI infrastructure

- **Rationale → Network Transformation:**
  - Operational complexity is growing.
  - Cost structure is not sustainable.
  - Legacy management architecture is no longer adapted.

- **Ultimate Goal:** Realize carrier-grade autonomic management

- **Means:**
  - Design a **Unified Management Framework** for the federation/unification of self-management approaches, principles and architectures
  - Design **algorithms/functions** with self-x and cognitive capabilities and empower the network by embedding this intelligence right into the management systems and network equipment
  - Impact the **industry** by demonstrating the possibility to deploy autonomic solutions in carrier grade networks, assess impacts and develop strategies for operators to adopt autonomic solutions
  - To bring confidence to **autonomics-empowered products** by developing standard processes for certification and testing

- **UPRC Role:**
  - WP2 “Unified Management Framework” Deputy Leader
  - Use Case Manager

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At A Glance: UniverSelf

**Project website:** [www.univerself-project.eu](http://www.univerself-project.eu)

**Project Coordinator:** ALBLF

**Project Partners:** 17 Partners in Europe + NTT Japan

**Duration:** September 2010 - November 2013

**Funding scheme:** IP

**Total Cost:** € 16.5m

**EC Contribution:** € 10.5m
Emerging assets: Management of ICT Infrastructures: UniverSelf: Use Case Lifecycle

- Starting point: a set of daily, operator big problems (use cases)
  - Variable types of segments/application domains (service/network, wireless/wired etc)
- Problem statements => Design of Network Empowerment Mechanisms (NEMs):
  - autonomic solutions i.e. a set of self-x, learning, policy-based methods/algorithms to solve those problems.
- Requirements (functional, non-functional, high level) => “Unification” engine
  - highly reusable, generic Functional Blocks (FBs) and Interfaces to embody the autonomic solutions in the management framework

- Unification achieved; ensuring the maximum overlap with past and simultaneous use-cases embodiments and generalizing what has been designed specifically.
- Validation; through analytical methods, simulations, and experiments in testbeds and/or prototypes, while also evaluating business impact and certification by considering trust and confidence metrics.

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Emerging assets: Management of ICT Infrastructures: UniverSelf: UMF Core

Network Empowerment Mechanisms (NEMs)

- Solve a specific problem in a specific, autonomic way
- NEM = method + objective + context
- Target: a seamless deployment and trustworthy interworking of a large number of NEMs → we need more:
  - Tools to deploy, drive and track progress of NEMs
  - Tools to avoid conflicts, ensure stability and performance when several NEMs are concurrently working
  - Tools to make NEMs find, formulate and share relevant information to enable or improve their functioning
  - Tools to allow NEMs getting monitoring data and enforcing configuration actions at equipment level
- 3 challenging research topics: Governance, Coordination and Knowledge.
  - The need to focus on these challenges led us to define the UMF Core.

Unified Management Framework (UMF)

- Offers/ensures
  - Plug n’ play deployment of “UMF-compliant” NEMs
  - Governance of NEM behavior
  - Exchange of always up-to-date Knowledge
  - Coordination of autonomic NEMs/NEMs interactions (incl. Orchestration, conflict avoidance, joint optimization) among NEM actions in a unified manner for all NEMs, independently of their method/scope/domain

Kostas Tsagkaris, Panagiotis Demestichas, Gerard Nguengang, Imen Grida Ben Yahia, Samir-Ghamri Doudane, Laurent Ciavaglia, "Identifying standardization opportunities for an autonomic network and service management framework (a European research project perspective)", submitted to IEEE Communications Magazine
Emerging assets: Management of ICT Infrastructures: UniverSelf: Case study

- **UPRC authors/manages “Operator-governed, end-to-end, autonomic, joint network and service management” use case**

- **Context:** provide a unified, goal-based, autonomic management system for the service deployment and/or new traffic accommodation
  - operators can express their goals and govern (control) their self-x capable network achieve end-to-end integration, federation of wireless/wired access and core/backhaul network segments and their associated management systems
  - maintain and exploit always-up-to-date inventories and knowledge in all the situations above
  - provide an optimized resource provisioning for RAN and Core (backhaul) segments, based on policies and knowledge

- **UPRC design and specification of NEMs/UMF solutions for autonomic service deployment and resource provisioning**

- K. Tsagkaris, P. Demestichas, G. Nguengang, I. Grida Ben Yahia, P. Peloso, “Unveiling technical challenges for the governance of end-to-end service delivery and autonomic infrastructures”, accepted for presentation in the IEEE Global Communications Conference (GLOBECOM 2012), December 2012, Anaheim, California, USA
Emerging assets: Management of ICT Infrastructures: UniverSelf: NEM Skin

NEM skin objective in the UMF

- Derives from the need for a common base for all network empowering mechanisms (NEMs)
  - The management layer must somehow be able to control and coordinate NEMs as well as supply them with required inputs
  - Technological heterogeneity is abstracted at the NEM level while the required info/commands are propagated into the framework in a UMF-compliant way, therefore,

- The NEM Skin consists of
  - the specifications a NEM must meet (i.e. the interfaces and info exposed to UMF)
  - and the means to accomplish this (i.e. a REST-based API targeted for developers)
Emerging assets: Management of ICT Infrastructures: UniverSelf: Governance of autonomic wireless access and core network segments

- Easy to use Human-to-Network interface
- UMF compliant communication
- Specification of models for services, users, infrastructure and the environment
- Definition of high level policies and business goals
- Translation to service and network level policies

Model examples

- Start / end time of a time zone
- Mobility types of users

Policy examples

- IF load is HIGH AND Location IS City Center THEN maximize throughput

Emerging assets: Management of ICT Infrastructures: UniverSelf: Knowledge Building with the Self Organizing Map (SOM) [1|2]

- Unsupervised machine learning technique based on neural networks
- Projection of high-volume, multidimensional data in 2D maps
  - maps consist of rectangular or hexagonal cells on a regular grid
  - similar data are presented on adjacent cells
- Representation of similarity and classification of the inserted data
- Flexible: minor limitations as to the field of application
  - easy to try different sets of input parameters
- Different approaches attempting to enhance the basic algorithm
  - selected a hybrid (Growing + Parameter-Less) to be used online for continuous adjustment to the changes in data
Emerging assets: Management of ICT Infrastructures: UniverSelf: Knowledge Building with the Self Organizing Map (SOM) [2|2]

Targeted Network Segment and Objective

- **Load Level Estimation (LLE NEM)**
  - **Wireless Access**: learn the patterns of offered load based on observations of implicit factors such as the area and time of day, day of week etc.
  - Past measurements (i.e. tuples of load per location and time) are fed as input

Clustered “pixels”, depicting the load level per area, day of week, or time of day, capable to estimate the load in the area in question.

Emerging assets: Management of ICT Infrastructures: UniverSelf: Core Networks [1|3]

- **Problem Statement:** find the most suitable routing configuration to accommodate traffic demands, satisfying operator's policies

- **Proposed Solution:**
  - CORE Routing Optimization NEM (for MPLS core networks)
  - CORE - Multilayer Traffic Engineering: IP/MPLS over DWDM (for optical core networks)
Emerging assets: Management of ICT Infrastructures: UniverSelf: Core Networks [2|3]

Single-layer Traffic Engineering (SLTE): IP/MPLS Core Networks

- **Problem Statement**: find the most suitable LSP or LSPs to accommodate the new traffic demand according to the operator’s objectives, while respecting the capacity of links.
- **Proposed Solution (CORE Routing Optimization NEM)**:
  - (Re-)Computation of MPLS paths
  - Load Balancing
  - Energy Efficiency
- **Evaluation**: comparisons between the two objectives, comparisons with various routing schemes
Emerging assets: Management of ICT Infrastructures: UniverSelf: Core Networks [3|3]

Multi-layer Traffic Engineering (MLTE): IP/MPLS over DWDM Core Optical Networks

- **Problem Statement:** find the most energy-efficient lightpath to accommodate the new traffic demand, while respecting the capacity of fibers and wavelengths.

- **Proposed Solution (CORE - Multilayer Traffic Engineering: IP/MPLS over DWDM):**
  - **Energy efficiency** is achieved through the allocation of traffic to dedicated lightpaths, which are restricted at the optical layer only (optical bypass), when this is possible.

- **Evaluation:** comparisons with energy-efficient routing schemes

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- RAN is invoked to accommodate a request (anticipated load)
- In OFDMA-based (LTE) case this may result in solution by means of appropriate self-organizing network (SON) functions to handle radio resource allocation and scheduling
- Design of SON functions as autonomic management solutions (NEM) to address optimization problems, taking into account Policies, Profiles, Context
  - Inter-Cell Interference Coordination (ICIC) is formulated to find the appropriate resource allocation in the target cell so as to minimize the interference caused at the target cell’s users
  - Coverage and Capacity Optimization (CCO) is formulated to find the appropriate resource allocation in the target cell so as to maximize the throughput in the target cell (capacity optimization), while its users experience acceptable channel quality (coverage optimization).
- Implementation using a set of Programming Languages and Tools (Java, Matlab), as well as Methods (Genetic Algorithm, Simulated Annealing Algorithm)

Total throughput in target cell vs generations with and without relative narrowband transmit power (RNTP) signaling in ICIC using genetic algorithm implemented in Java for a scenario of 45 users

Emerging assets: Management of ICT Infrastructures: UniverSelf: SON Coordination

- Coordination of simultaneously operating SON functions in order to avoid conflicts and network instabilities
- Consideration of SON coordination within UniverSelf Unified Management Framework (UMF)
  - Coordination Block to coordinate autonomic management solutions (NEM)
- Multi-objective Optimization
  - Pareto Optimal
  - Weighted Sum Method
  - $\epsilon$-Constraint Method
  - Weighted Metric Methods
- Evolutionary Game theory
- Game Theory
- Coordination via Utility Functions Policies
- Compliance with 3GPP SON logical architecture

ICIC and CCO coordination in comparison with the individual ICIC and CCO optimal solutions using NSGA-II algorithm implemented in Matlab for a scenario of 12 users

- P. Vlacheas, E. Thomatos, K. Tsagkaris, P. Demestichas, "Operator-governed SON Coordination in downlink LTE Networks", Future Network and Mobile Summit 2012, 4 - 6 July 2012, Berlin, Germany
- P. Vlacheas, K. Tsagkaris, P. Demestichas, "Policy-driven Autonomic Coordination among ICIC and CCO in downlink LTE Self-Organizing Networks", submitted for publication in IEEE Communications Letters
Emerging assets: Management of ICT Infrastructures: UniverSelf: SON Coordination

- Demonstration Platform for “Conflict-free coordination of SON functions” (SON LTE Use Case) in the context of Bell Labs Open Days 2013 (June 18-20), Villarceaux, France
- Conflict resolution through separation in time
- Achievements:
  - Ensures stability, convergence and trustworthy NEM interworking
  - Provides the operator with the means to govern the NEMs
Emerging assets: Management of ICT Infrastructures: 
UniverSelf: Prototyping environment based on REST

- Implementation of the RESTful interfaces to/from the UMF Core, as well as some of the most critical aspects of the NEM model regarding the manifest, the mandate, the actions, information and configuration options.

- The final result is:
  - a single point of updating the UMF-related part of all NEMs, UMF compliance for the NEM developer without having to be aware of any protocol-specific details, and an API that might potentially be used with a communication technology other than REST

- Technical details:
  - Use of the Simple Framework for WS deployment, and the Resty library for invocation (both very lightweight and small-sized), while
  - XStream is handling the (de) serialization of JAVA objects (from) to XML

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<th>Server Side</th>
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Emerging assets: Management of ICT Infrastructures: UniverSelf: Prototyping environment based on JADE

- Based on JADE platform, FIPA compliant solution
- UMF entities (Knowledge, Coordination, Core mechanisms, NEMs) represented in the prototyping environment by one or more agents
- Loose integration, support of autonomicity, facilitation of embodiment of intelligence
Emerging assets: Management of ICT Infrastructures: UniverSelf: Trust assessment

Trust assessment and validation of autonomic control loops

... we built knowledge on the trustworthiness of the decisions or of a control loop for choosing:

1. the most trustworthy decision of a control loop
2. the most trustworthy control loop to achieve a goal

Using the specific metrics ...

*Different observable parameters may be considered for diverse Control Loops

Emerging assets: Cloud - IoT Platforms:  
iCore: Internet Connected Objects for Reconfigurable Eco-systems

✦ Main direction: Open cognitive framework for the Internet of Things  
(i) Virtual Objects (VOs): Cognitive virtual representations of real-world objects (RWOs) and digital objects (DOs)  
(ii) Composite Virtual Objects (CVOs): Cognitive mash-ups of semantically interoperable VOs  
(iii) Users/stakeholders perspectives

✦ Requirements:  
- Address heterogeneity of objects of the Internet of Things (IoT)  
- Increase the reusability of objects, outside the scope in which they were originally deployed (e.g. a traffic monitoring or security camera to be used for the creation of the digital representation of any object)  
- Increase reliability, availability of services and energy efficiency  
- Allow business integration of the views of multiple stakeholders in the composition of services

At A Glance: iCore

Internet Connected Objects for Reconfigurable Eco-systems

Project Coordinator: CREATE-NET  
Project website: http://www.iot-icore.eu  
Partners: CREATE-NET, AMBIENT, A-LBELL, ALBLF, AOSAE, CRF, ZIGPOS, JRC, IT21, SAG, SIEMENS, TCS, TI, TNO, TU DELFT, UNIS, UPRC, VTT, WSN, NTT

Duration: October 2011 - September 2014

Funding scheme: IoT  
Total Cost: €13,596,984  
EC Contribution: €8,707,000
Emerging assets: Cloud - IoT Platforms: iCore: Internet Connected Objects for Reconfigurable Eco-systems

- **VOs** comprise cognitive mechanisms (self-management and learning capabilities)
  - Offering information and knowledge on the RWO/DO context of operation (e.g., location, availability of energy, computing, storage, communication resources, etc.) and profile (capabilities).
  - Transforming raw measurements to knowledge

- **CVOs**: use VOs, and deliver services in accordance with the user/stakeholder requirements.

- Cognitive entities at all levels provide the means for self-management (configuration, healing, optimization, protection) and learning

- Validation use cases: ambient assisted living, smart office, smart cities transportation, and supply chain management and logistics

Source: iCore Consortium
Cognitive management framework for IoT

- Functionalities and enablers that facilitate the autonomous, dynamic creation, instantiation and configuration of CVOs and VOs taking into account user and application requirements.

- Capabilities for learning, applying known solutions, and therefore, reducing the time needed for handling of requests from the User and/or Application level.

- Implementation of corresponding demonstration platform also includes various sensors and actuators.

Emerging assets: Cloud - IoT Platforms: iCore: Internet Connected Objects for Reconfigurable Eco-systems
Demonstration Platform for Assisted Living Use case

Basic storyline:

- Sara is an elderly lady living at home. She has opted for an assisted living service. All necessary equipment is installed in Sara's home.
- At the corresponding medical center a member of staff provides requirements through an appropriate interface.
- Cognitive functionalities take into account provided requests and policies and dynamically create a CVO as a mash-up all of necessary objects to fulfill the requested application.
- The derived solution (CVO composition) is recorded so that the next time a similar request is issued by the medical center knowledge on past CVO instantiations enables the direct deployment of the known CVO.

Technical aspects

- For sensing of the environmental conditions and Sarah's health state, the WaspMote platform by Libelium is used. The platform includes wireless (IEEE802.15.4, ZigBee) gateway and a number of wireless sensor nodes.
- Three actuating devices: a fan, a red Light Emitting Diode (LED), and a Lamp, that are connected to Arduino platform.
- The WaspMote and the Arduino are connected, through the internet, with the Cosm online databases.
  - The WaspMote uploads the sensor measurements
  - The Arduino reads the commands from the application that is used in the Medical Centre.
Demonstration Platform Awards

- **Future Network and Mobile Summit 2012**
  - iCore won the "Runner Up Demonstration Stand Award"

- **Future Network and Mobile Summit 2013**
  - iCore won "the Best Demonstration Award"
  - The iCore paper "A Cognitive Management Framework for Service Provisioning in the Internet of things", co-authored by V. Foteinos, D. Kelaidonis, G. Poulios, P. Vlacheas, V. Stavroulaki, P. Demestichas, won "the Second Best Paper Award"
**VOs & VO Registries**

- **Virtual Objects (VOs):**
  - are virtual representations of Real-World Objects (RWOs), which may be either digital objects with Information and Communication Technologies (ICT) capabilities or non-ICT objects.
    - **ICT objects** include objects such as sensors, actuators, smart phones, etc.
    - **Non-ICT objects** are tangible objects of the physical world without direct ICT capabilities e.g. furniture, a room, fruits, a person, etc. Non ICT objects can be implicitly represented in the virtual world through their association with one or more ICT objects, which in turn are represented through VOs.

- **VO registries:**
  - store VO descriptions, in order to enable their accessibility anytime from anywhere.
  - may be distributed across several domains.
  - Implemented as RDF Graph Database with the use of the Sesame framework
    - Allows SPARQL queries
    - Accessible via RESTful Web Service (WS)
CVOs & CVO Registries

- **Composite Virtual Objects (CVOs):**
  - are cognitive mash-ups of semantically interoperable VOs that render services in accordance with user/stakeholder perspectives and application requirements.
  - are self-managed, self-configurable components, which exploit cognitive mechanisms to enable the re-use of existing VOs and CVOs by various applications, also outside the context and domain for which they were originally developed.

- **The CVO registry**
  - contains information for each deployed CVO
  - The information includes:
    - (a) CVO identifier
    - (b) request parameters that led to the creation of the CVO
    - (c) situation parameters that represent the context in which the CVO was created
    - (d) the VOs that comprise the CVO
Emerging assets: Cloud - IoT Platforms: iCore: Internet Connected Objects for Reconfigurable Eco-systems

Request & Situation Matching

- Identifies the closest reference situation and corresponding request for the newly acquired situation and request.
- Compares incoming application request $x$ to recorded ones $y_n$
  - Both request and situation parameters
  - Consideration of approximate functions
    - Determination of suitability of previously created CVOs through correlations between VOs functions and requested functions in a matrix:
      - Image can be fully satisfied by video capture ($c=1$)
      - Video can be partially satisfied by image ($c=0.5$)
  - Selection of the most similar $y_i$ (satisfaction-rate based similarity metric $S$) with similarity $S(x, y_i)$

|       | image | video | ...
|-------|-------|-------|------
| image | 1     | 1     |      |
| video | 0.5   | 1     |      |
|       |       |       |      |

S($x, y_i$) > $S_{thresh}$?

- Yes:
  - Re-use the CVO created for the past application request $y_i$
- No:
  - Overhead at early stages of the system
    - Reusability
    - Performance Gain
    - Context Awareness
    - Trigger Decision Making process
Emerging assets: Cloud - IoT Platforms: iCore: Internet Connected Objects for Reconfigurable Eco-systems

Request & Situation Matching

Area of interest and corresponding available VOs

Situation and Request Acquisition and Matching – User Interface

time of request

Request parameters: functions & policies
Emerging assets: Cloud - IoT Platforms:
iCore: Internet Connected Objects for Reconfigurable Eco-systems

Request & Situation Matching

- incoming request and corresponding situation will be used to find the most similar past composition and the situation based on which it was created:
  - time of request, functions requested, available VOs

- rank the past application requests to best match the new request
  - pass the request down to the decision making mechanisms, unless there is one similar to the new (SR > 90%)

Records of past application requests

Satisfaction Rate (SR)-based ranking (down towards the worst match)

known correlations (proximity) between functions

CVO deployment

request parameters [R]

situation parameters [S]
Emerging assets: Cloud - IoT Platforms:
iCore: Internet Connected Objects for Reconfigurable Eco-systems

Decision Making

- Given a set of available VOs, a set of functions, a set of utilities, a set of costs, weights for utilities, weights for costs, correlation matrix for functions, utility values, cost values, find the optimal composition of VOs to fulfill the requested functions.

- Process
  - Acquisition of situation and request parameters
  - Retrieval of records of available VOs from the VO registry
  - Decision for the optimal CVO composition is based on the maximization of an objective function, which takes into account all aforementioned information

REQUEST FOR NEW CVO:

<table>
<thead>
<tr>
<th>Requested Functions / Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Temperature</td>
</tr>
<tr>
<td>QUA: 0.01, PER: 0.01, SEC: 0.01, EXP: 0.01, NET: 0.01, ENE: 0.01</td>
</tr>
</tbody>
</table>

AVAILABLE VOS

<table>
<thead>
<tr>
<th>ID</th>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>QUA</th>
<th>PER</th>
<th>SEC</th>
<th>EXP</th>
<th>NET</th>
<th>ENE</th>
<th>AG-VAL</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="http://iCore/vo/VO001">http://iCore/vo/VO001</a></td>
<td>Room Temperature</td>
<td>840.34 - 837.04</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>0.11</td>
</tr>
<tr>
<td><a href="http://iCore/vo/VO002">http://iCore/vo/VO002</a></td>
<td>Room Humidity</td>
<td>757.65 - 1097.55</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>0.11</td>
</tr>
<tr>
<td><a href="http://iCore/vo/VO010">http://iCore/vo/VO010</a></td>
<td>Audio Playback</td>
<td>537.39 - 951.58</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
<td>0.07</td>
</tr>
<tr>
<td><a href="http://iCore/vo/VO010">http://iCore/vo/VO010</a></td>
<td>Video Playback</td>
<td>537.39 - 951.58</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
<td>0.08</td>
</tr>
<tr>
<td><a href="http://iCore/vo/VO003">http://iCore/vo/VO003</a></td>
<td>Luminosity Measuring</td>
<td>670.1 - 1030</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>0.11</td>
</tr>
<tr>
<td><a href="http://iCore/vo/VO115">http://iCore/vo/VO115</a></td>
<td>Body Temperature</td>
<td>799.9 - 908.38</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>0.03</td>
</tr>
<tr>
<td><a href="http://iCore/vo/VO115">http://iCore/vo/VO115</a></td>
<td>Body Pulse</td>
<td>799.9 - 908.38</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>0.11</td>
</tr>
<tr>
<td><a href="http://iCore/vo/VO003">http://iCore/vo/VO003</a></td>
<td>Luminosity Measuring</td>
<td>568.39 - 1067.89</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>0.11</td>
</tr>
<tr>
<td><a href="http://iCore/vo/VO015">http://iCore/vo/VO015</a></td>
<td>Body Temperature</td>
<td>799.9 - 908.38</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>0.11</td>
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PROPOSED CVO

<table>
<thead>
<tr>
<th>ID</th>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>QUA</th>
<th>PER</th>
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<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>0.11</td>
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</tbody>
</table>

VOs comprised in proposed CVO

<table>
<thead>
<tr>
<th>ID</th>
<th>FUNCTION</th>
<th>LOCATION</th>
<th>QUA</th>
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<td>High</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

Solution Value: 0.36

Requested Functions / Policies

Requested Functions:
- Body Temperature
- Light
- Emergency Alarm
- Body Pulse
- Luminosity Measuring
- Room Cooling
- Room Temperature

Policies:
- QUA: 0.01
- PER: 0.01
- SEC: 0.01
- EXP: 0.01
- NET: 0.01
- ENE: 0.01
Emerging assets: Cloud - IoT Platforms:
iCore: Internet Connected Objects for Reconfigurable Eco-systems

References


Emerging assets: Smart Wireless Access: ARTEMIS: Cognitive ecosystem for energy efficiency

- **Basic concept:** to develop a cognitive ecosystem targeting the reduction of the energy consumption that derives from wireless technologies and applications

- **Research topics on which the project focuses:**
  - Energy efficiency at device level
  - Energy efficiency at network level
  - Energy efficiency at system level
  - Application Design and Implementation

**Motivation for China**
- 12th Five-Year Plan: 16% CO₂ reduction
- 3 operators consume 0.8% of energy
- >80% of energy for wireless networks
- To improve the sustainability of economy through worldwide collaborations

**Motivation for Greece**
- EU Energy Efficiency Plan 2011: 20% energy saving by 2020 & Up to 28% energy savings for buildings
- Home & access networks major consumers
  - To open a market & reinforce the economy

**Expected results**
- Holistic energy management for wireless technology (device, network, system, application level): design principles
- Improvements with respect to evaluation metrics for energy efficiency in the wireless ecosystem
- Cognitive mechanisms for intra-, inter-level energy aware optimization
- Novel mobile applications for energy efficiency
  - Home network application scenario & test-bed for energy efficiency

**At A Glance: ARTEMIS**

**Project website:** [http://tns.ds.unipi.gr/artemis-project/](http://tns.ds.unipi.gr/artemis-project/)

**Project Partners Greece:** UPRC, Velti

**Project Partners China:** China Mobile, BUPT

**Duration:** April 2013 - September 2015

**Funding scheme:** Greece-China bilateral cooperation

**Greek Partners’ Budget:** €538,600

**GSRT Contribution:** €392,169
Emerging assets: Smart Wireless Access: AutoSDN: Autonomics and Software Defined Networking: Instantiation to LTE SON

Main objectives:
- Study the relation/compare of Autonomics with Software Defined Networking (SDN)
- To designate an Autonomic/SDN framework for the management and control of modern telecommunication networks/services
- To instantiate and validate the framework to an LTE SON Het Network

"Programmable SON"
Dynamic deployment, instantiation, and coordination (conflict detection/resolution) of different SON (autonomic) algorithms such as Load Balancing, Interference Coordination, Admission Control etc.

Live Conflict Graphs
Live Metric Plots
Network view & control/config

At A Glance: AutoSDN
A Study of the link among Autonomics and Software Defined Networking: Instantiation to LTE SON
Partners: Orange Labs & University of Piraeus Research Center
Duration: 1st April 2013 – 31st March 2014
Funding scheme: Externalized Research Contract
Total Cost: €45,000

“LoadBalancing”
drag’n’drop to deploy
over Cell D

Generic Control API
SON Function e.g. LB

(0)
Emerging assets: Smart Wireless Access: AutoFlow (Geant) (Autonomic OpenFlow)

- **Main objectives:**
  - To meticulously study the GÉANT OpenFlow facility so as to gain a thorough awareness of the provided testbeds;
  - To provide a detailed description and specification of the AUTOFLOW experiments, in terms of scenarios, performance and validation metrics;
  - To set up the AUTOFLOW experimentation framework as part of GÉANT OpenFlow facility, by integrating our components with the testbeds;
  - To instantiate and validate the derived ANM/SDN-based framework (interplay) to problems appearing in modern, core networks e.g. traffic engineering;
  - To conduct the experiments, derive and evaluate the results that will be exploited for refinement of the AUTOFLOW experimentation framework.

**At A Glance: AutoFlow**

**Autoonomic OpenFlow**

**Partners:** GEANT members  
**Duration:** Q4-2013 - Q2-2015  
**Total Cost:** €229,5k  
**EC Contribution:** €179k

**Appropriate Placement of ANM Core to the SDN/ OpenFlow facility**

**AUTOFLOW** introduces Autonomic Network Management (ANM) to GÉANT OpenFlow-enabled facility
Emerging assets: Smart Wireless Access:
Acropolis NoE: Advanced coexistence technologies for radio optimisation in spectrum

- **Rationale:** Research and develop optimisation techniques for cooperative and cognitive wireless systems
- **Objectives:** Realise Joint Research Activities within the Consortium so as to strengthen European knowledge and leadership in the focused area of cooperative communications with coexistence specifically considering the intersection of cognitive radio, opportunistic spectrum access, flexible radios, and self-organizing networks.
- **Focus on** the education of European researchers on advanced coexisting and cooperating communication technologies
- **Impact on** harmonization of European research

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**At A Glance: ACROPOLIS**

Advanced coexistence technologies for radio optimisation in licensed and unlicensed spectrum

Project Coordinator:
King’s College London (KCL)

Project website: www.ict-acropolis.eu

Partners: RWTH, Uniroma1, IASA, TUD, UPRC, EIT+, KCL, KTH, UKIM, CTTC, JRC, PUT, UoS, EURECOM, UnivLeeds, EADS

Duration: October 2010 - December 2013

Funding scheme: NoE

Total Cost: €4.13m
EC Contribution: €3m
Emerging assets: Smart Wireless Access: Acropolis NoE: Advanced coexistence technologies for radio optimisation in spectrum

- WP11 Leadership: Learning Mechanisms and Knowledge Management
- Joint research activities, leading to publications in Journals, Conferences and Workshops [1-7]
- PhD courses elaboration (voice over ppt)
- Presentations in the context of Summer Schools

Knowledge based management of reconfigurable B3G infrastructures

Legacy assets: Smart Wireless Access: OneFIT: Networking schemes for wireless access to the Future Internet

Opportunistic networks
- Operator governed (through resources, policies, and information/knowledge)
- Coordinated with the infrastructure
- Comprise network elements of infrastructure and devices (envisaged in the Future Internet)
- Building on: spectrum management, secondary usage, infrastructure-less networks, social networks
- Context, profile, policy, knowledge-aware routing

Cognitive management systems
- Provide the means for feasibility determination, creation, maintenance, handling of forced terminations

Requirements:
- Numerous diversified applications, social networking, prosumer concept -> applications with a “localized” interest
- Machine-to-Machine (M2M): communication without (or only limited) human intervention
- Increased interest for wireless
- Utmost efficiency in resource provision (resource utilization, “green” decisions, further lower costs)
- Resolve potential congestion situations, expand infrastructure coverage when/where temporarily needed, efficiently offer localized applications and content

Control Channels for the Cooperation
- Information definition, signaling flows, protocols (packet structures, exchange)

At A Glance: OneFIT
Opportunistic networks and cognitive management systems for efficient application provision in the Future Internet

Project website: www.ict-onefit.eu
Project Coordinator: UPRC/ TNS
Duration: July 2010 - December 2012
Funding scheme: STREP
Total Cost: € 6,7m
EC Contribution: € 3,9m

**Functional Architecture**

- **Main building blocks**
  - **OneFIT functional entities:**
    - CSCI: Cognitive management System for the Coordination with the Infrastructure
    - CMON: Cognitive Management system for the Opportunistic Network
  - **Legacy functional entities:**
    - DSM: Dynamic Spectrum Management
    - DSONPM: Dynamic, Self-Organising Network Planning and Management
    - JRRM: Joint Radio Resources Management
    - CCM: Configuration Control Module
  - **Elaboration and improvement of DSONPM**

- Mapping of UPRC’s proposed functionalities for CSCI/CMON to the OneFIT Functional Architecture

- Identification of terminals that are located in a problematic area (e.g., congested service area of a BS) and need access to alternate infrastructure elements through neighboring terminals

- Decision on what algorithm to run in order to solve the capacity extension problem

- Formation of ON paths for each terminal in the congested area. Allocation of terminals from congested BSs to alternate BSs

- Solution enforcement

- Management of users’ profiles
- Terminal capabilities (e.g., does the terminal support ON etc.)

- Assignment of power levels to femtocells
- Distribution of terminals to femtocells
- QoS allocation to terminals

- Users profiles
- Terminals capabilities

- Status of infrastructure elements
- Status of terminals

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- OneFIT D2.2 "Functional and system architecture", February 2011
Legacy assets: Smart Wireless Access: OneFIT: Control Channels for the Cooperation of Cognitive Management Systems (C⁴MS)

- **C⁴MS** is proposed as a logical channel which conveys information related to the network among CSCI and CMON functional entities.
- **TNS** members have contributed to:
  - Definition of data structures for the conveyed information related to profiles, context, policies, knowledge, decisions.
  - Estimation of signalling load conveyed through **C⁴MS**.
  - ETSI TR 102 684 "Feasibility Study on Control Channels for Cognitive Radio Systems".

ETSI TR 102 684 “Feasibility Study on Control Channels for Cognitive Radio Systems”

Indicative formula and signalling load evaluation of BS and Terminal Profiles:

$$BS/Terminal\_Profile = 35 + \sum_{i=1}^{\alpha} (18 \cdot x_i + 1)$$

where
- $\alpha$ = number of interfaces, $\alpha \geq 1$
- $x_i$ = number of RATs (per interface), $x_i \geq 1$

Indicative data structure of "Profiles"
Legacy assets: Smart Wireless Access:
OneFIT: Capacity extensions: Algorithms for Dynamic Resource Allocation to small cells

- **Rationale:**
  - An infrastructure element (e.g. macro Base Station) experiences congestion issues and available small cells (e.g. femtocells) are located in range of its service area

- **Solution:**
  - **Capacity extension:** Available small cells (e.g. femtocells) can be seen as an asset that provide capacity extension to overloaded infrastructure elements
  - **Extra resources:** Femtocells can seize the opportunity of the radio environment (extra resources) in a specific region for a specific timeframe
  - **Energy efficiency:** Femtocells are configured to the minimum, possible power level needed to acquire the most possible traffic

- **Minimum power level assignment to femtocells; comparison of results of:**
  - Dynamic Resource Allocation (UPRC’s proposed algorithm)
  - Simulated Annealing
  - Tabu Search

- **BS energy consumption in relation with the number of femtocells:**
  - Energy consumption decreases as more femtocells are deployed in the service area

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- **Rationale:**
  - A localized region where there is a traffic hot-spot; congestion situation needs to be resolved

- **Solution:**
  - **Capacity extension through neighboring terminals:** An operator-governed opportunistic network is created in order to redirect the traffic to alternative (non-congested) infrastructure elements
  - **Extra resources:** Neighboring available terminals are able to
  - **Energy efficiency:** Energy savings of the previously congested infrastructure (and its attached devices) is observed

- **Average delay for the transmission of a whole message**
  - The delay decreases about 25% in average after the solution enforcement

- **Average transmission power of the congested BS before and after the solution enforcement**
  - Energy savings increase as more terminals switch to ONs

---

Legacy assets: Smart Wireless Access: OneFIT: Coverage Extensions: Algorithms for the selection of nodes based on a fitness function

- **Rationale:**
  - A device (e.g. mobile, laptop or camera) is out of the coverage of the infrastructure, due to lack of coverage or a mismatch in the Radio Access Technologies (RATs)

- **Solution:**
  - **Coverage extension (selection of nodes through fitness function):** An opportunistic network is created in order to serve this device. Selection for participation in the opportunistic network of the appropriate subset of nodes, among those that happen to be in the particular area takes place.
  - **Fitness function:** Taking into account Energy level of node $i$ ($e_i$); Availability level ($a_i$) - including node capabilities (supported RATs/ frequencies), status of active links, mobility levels, location; Delivery probability ($d_i$)

- **Impact on number of messages losses**
  - As less but better nodes are selected to participate in an ON (according to the fitness function), the number of message losses is expected to decrease

- **Impact on lifetime of an ON**
  - As less nodes are selected to participate in an ON, these nodes are more stressed in terms of energy resources and the lifetime of the ON is expected to decrease
Legacy assets: Smart Wireless Access: OneFIT: Proof of Concept and Demonstrations

- Demonstration of the scenarios
  - Coverage extension
  - Capacity extension through neighboring terminals
  - Capacity extension through femtocells (Dynamic Resource Allocation)

- CSCI and CMON agents have been developed using JADE in order to exchange messages

- Integration of JADE with ONE (Opportunistic Network Environment)


- **MCAPs capabilities**
  - Move in an autonomous manner
    - Carried by humans, vehicles, moving robots
  - Establish a radio network in short time
    - Ad-hoc connectivity
  - Limited centralized management

- **MCAPs are able to handle demanding situations**
  - Moving hotspots
  - Areas that lost their infrastructure
  - Areas with hard morphology (isolated areas, caves, etc.)

- **Main objective**
  - Solution of an optimization problem that will find
    - The configuration of the MCAPs radio network
    - The final positions of the MCAPs
    - The trajectories that the MCAPs need to follow
  - Development of solutions based on
    - Meta-heuristics (Simulated Annealing, Tabu Search)
    - Bio-inspired algorithms (Ant Colony Optimization, Fruit fly Optimization Algorithm)

---

**At A Glance: MCAPs**

**Strategies for Creating Networks of Moving Cognitive Access Points**

Project Partner: UPRC/ TNS

Funding body: U.S. Office Naval Research (U.S.A. / UK)

Partners: UPRC/ TNS,

Duration: May 2012 – April 2013

Total Cost: $42,000
Legacy assets: Management of ICT Infrastructures:
E³: Cognitive wireless networks: cognitive network management, self-organizing network (prototype)

- **Input**
  - Context: traffic, mobility, interference, element status
    - Change of element status, e.g., fault of some component like TRX → trigger for self-healing mechanisms
  - Profiles: equipment, application, user requirements and preferences
  - Policies: optimization objectives, strategies, constraints, strategies

- **Optimization mechanisms**
  - Algorithms for various time scales, optimal or near-optimal
  - Short time scale: greedy, online
  - Mid-term: simulated-annealing, taboo search, genetic algorithms

- **Output**
  - Configuration at various levels
  - Radio Access Technology and spectrum selection per BS/TRX
  - Interconnection of network elements
  - QoS level determination per user class

- **Learning**
  - Contexts encountered in time space
  - Solutions applied, resources used, and efficiency exhibited
  - OFDM case: subset of subcarriers that can be used

- **Impact**
  - Optimal QoS, operational efficiency, automation of tasks, minimization of human involvement, reduction of operational expenditure (OPEX) and of capital expenditures (CAPEX) (avoid worst case based planning)
Legacy assets: Management of ICT Infrastructures: E³: Management functionality for cognitive devices (software prototype)

- Knowledge-based, reactive and proactive, learning-based, handling of situations
- Selection and enforcement of optimal device configuration based on
  - Context (Monitoring, Sensing), profiles, policies
  - Negotiation (English, Dutch models)
  - Policies and profiles
  - Selection algorithms for operator-driven (policy-driven) connection with infrastructure or in ad-hoc mode
- Knowledge base: learning and exploiting experience on contexts most likely encountered, network and configuration capabilities, user preferences
  - Utilization of Bayesian networks, artificial neural networks:

- Implementation of prototype
  - Deployed on various devices: NOKIA 810, HP PDA
After identifying and describing the exact info to be conveyed...

- Setup of a platform to experiment on a IEEE 1900.4-based architecture, functionality and interfaces
- Multi-agent environment based on JADE (Java Agents DEvelopment framework)
- Performance assessment
  - Indicative scenarios
  - Results w.r.t. measured signalling load/delays

Legacy assets: Management of ICT Infrastructures: ENISA: An ontology for modelling resilience stakeholders and associated concepts

- End-To-End resilience to break down the different silos in resilience consideration
- Ontology to define concepts and their properties/relationships
  - Specification of the properties among Resilience classes and especially between Threats and Means per Domain
  - Specification of Policies, Profiles, Context in a resilient infrastructure

At A Glance: ENISA

Ontology and taxonomies for resilience

Project website: http://www.enisa.europa.eu/

Partners: Cadzow Communications Consulting Ltd. And University of Piraeus Research Center

Duration: January 2011 - June 2011

Funding scheme: P/30/10/TCD

Total Cost: €60,000

P. Vlacheas, V. Stavroulaki, P. Demestichas, S. Cadzow, D. Ikonomou, S. Gorniak, "Towards an end-to-end network resilience", International Journal of Critical Infrastructure Protection, accepted for publication

Legacy Assets: Device Management: Collaboration with Intel M.C.

**Overall goals**

- **Enhance the Quality of Experience offered to users**
- **Create Platform**
  - Exploit device capabilities, infrastructure/infrastructure-less communications
  - Intelligence (self-x, cognition, autonomous decisions)
  - Prepare for Internet of Things, machine-to-machine
- **Use technologies and concepts that can lower various cost factors (CAPEX, OPEX)**
- **Develop mechanisms for making green decisions**

**First collaboration**
- Platform establishment based on actual hardware
- Parameter extraction
- First demonstrations

**Second collaboration**
- Applications
- Multihoming
- Algorithms
Legacy Assets: Device Management: Collaboration with Intel M.C.

- **System architecture:** Developed by UPRC and IMC: Overarching Controller, WLAN Controller, IMC 3G Controller, Media player, Server

- **Upgrades**
  - Software based on Java/ C++
  - Modules integrated in a software platform running on a laptop
  - Platform upgrades in each phase of collaboration
Future interests: ICT infrastructures, management (1)

- All facets associated with networks, management, applications and services

- Training activities (MSc, PhD, undergraduates) related to the eTOM and other management models
- Research achievements with emphasis on resource and services development
- Research on management frameworks

Source: eTOM standard by TeleManagement Forum
Future interests: ICT infrastructures, management (2)

- **Main forthcoming research areas of interest**
  - Software Defined Networking
  - Trust in Autonomics
  - Big Data, Machine Learning, Knowledge
  - Autonomic Management of Cloud Resources
  - Cloud Platforms and IoT
  - Management for Energy-Efficient Wireless/Wireline Infrastructures
  - Proximity-based Services, Device-to-Device
  - Management for Shared Spectrum
Future interests: Future Internet era realisation

- FI era will be characterized by the penetration of more applications compared to today
- Grand objective: contribution to the building of an inclusive, cohesive, sustainable, prosperous society.
- Consequently, there will be (non-orthogonal) groups of applications
  - Smart city vision
  - Ecosystem (environment) protection
  - Value creation through advanced product manufacturing
  - Highly sophisticated digital services
  - Smart energy networks
  - Smart transportation
  - Smart content centric networks (CCNs)
Future interests: FI era: ICT and energy networks

Objectives
- High demand
- Sharing and exploitation of available renewable resources
- Find minimal cost allocation of energy production resources, minimise outages
- Decrease the environmental cost of production and transferring

Energy generation
- Renewable and legacy energy resources

Distribution network
- From resources

Transmission network
- To end users/consumers

Consumers
- Vehicles, electricity, smart homes, heating, computing

Energy generation
- Renewable and legacy energy resources
- Nuclear
- Fossil (coal, oil, natural gas, LNG)

The Energy mix:
- **Renewables** (solar, wind, hydro, biomass, geothermal, hydrogen)
- **Nuclear**
- **Fossil** (coal, oil, natural gas, LNG)

Technical Approach
- Interfaces among ICT and Grid Infrastructures
- Transfer of information and corresponding decisions, according to QoS requirements
- ICT infrastructure offers also processing/computing resources for reaching optimal decisions
Future interests: FI era: ICT and environment management

**Objectives**
- Minimum cost/ highly reliable acquisition of information
- Knowledge development through computations in the ICT infrastructure (and general devices)
- Decision enforcement

**Services to support**
- Emergency handling (fires, oils, floods, spill)
- Long term studies for sustainable development
- Security and safety

**Technical Approach**
- Business drivers, requirements engineering
- Device development/ Interface development
- Integration with ICT infrastructure
- Validation through prototyping experimentation and pilot with respect to business drivers
Future interests: FI era: ICT and intelligent transportations

Objectives (focusing on services)
- Dynamically resolve congestion situations
- Reduce time and increase the utilization of transportation means
- Reduce emissions, handle emergencies

Technical Approach
- Information extraction from the infrastructure
- ICT infrastructure for transferring information with QoS guarantees
- Processing/computing of optimal decisions potentially through ICT infrastructure means
- Provision of services and management

Achievements combining ICT and transport
- Car pooling system

- Cognitive networks and transportation infrastructures
Conclusions

- Aspects covered
  - Profile
  - Emerging and Legacy Assets related to the FI
  - Future Interests
    - Evolution of ICT infrastructures and services
    - Future Internet are realisation
    - ICT and energy, smart energy
    - ICT and transportation, intelligent transportation systems
    - ICT and environment management, sustainable growth