CAMELO: A Context-Aware Cloud Architecture for Smart Cities

Aymen El Amraoui[†] *and Kaouthar Sethom*[†],

University of Carthage, SMS Research Unit, Enicarthage, Tunisia

Summary
The "Smart City" concept is receiving a significant research effort, notably because of the population growth and the urbanization trend. In this new context, Cloud computing is expected to play a significant role making a better use of distributed resources, achieving higher throughput and tackling large scale computation problems. This paper presents CAMELO, a new context aware framework based on network virtualization functions to offer converged infrastructure and shared services. Our solution improves efficiency, reduce cost and raise environmental awareness when building adapted city services such as healthcare, traffic, police and municipal operations…

Keywords:
Cloud Computing; smart city; context-aware.

1. Introduction

Whereas until now the role of cities and regions in ICT-based innovation mostly focused on deploying broadband infrastructure, the stimulation of ICT-based applications enhancing citizens' quality of life is now becoming a key priority. As a next step, the potential role of cities as innovation environments is gaining recognition.

Smartness of a city is driven and enabled technologically by the emergent Internet of Things (IoT) - a radical evolution of the current Internet into a ubiquitous network of interconnected objects that gather information from the environments (sensing) and interacts with the physical world.

The applications within the urban environment that can benefit from a smart city IoT capability can be grouped on three main fields: citizens (health and wellbeing); transport (mobility, productivity, pollution); and services (critical community services).

More and more enterprises and projects begin to establish applications based on cloud infrastructures. From the perspective of business, cloud computing federates utility computing to make its computational and storage resources as a metered service just like traditional public utility (such as electricity, water or natural gas). From the perspective of a delivery model, cloud typically offers three representational service types which are Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS) respectively. These diverse delivery models enable cloud to offer different services for satisfying different requirement of customers. Cloud infrastructure is usually based on a unified computing architecture and this core structure contributes to ease of deployment, performance, management, and security of virtual environments. For all the above reasons, cloud computing may just be the right technology for smart cities infrastructure [1-2].
In order to integrate the ubiquitous urban sensing and the smart city applications, as well as to realize the full potential of Cloud computing, a combined framework with Cloud at the center is proposed in this paper.
The challenge in realization of smart cities through ICT lies in the integration of data from disparate sources and processing into useful information delivered through services, consumed by citizens and public administrations. As the context helps us to understand the living environment of a citizen at any time, our solution needs to be of course context-aware.
The remainder of this paper is organized as follows: Section 2 presents CAMELO, our context-aware Cloud Computing framework. In section 3, our context processing method is described. Finally, section 4 present performance results.

2. Architecture design

In this section, we will present the architectural design of **CAMELO** (Figure 1). It is implemented as part of MANO [3], which is regarded, as an NFV management solution.

A. Why NFV ?

The nature of traffic in smart city context in terms of connection count and bandwidth utilization is very dynamic and unpredictable. If the allocated static set of cloud resources (i.e CPU or the buffer/ cache/ swap / physical memory) are not sufficient to handle the number of connections, it will impact the service in terms of delay, packet loss, play-out interruptions, and will eventually downgrade the users' perceived quality.

To meet these challenges we first propose to use the NFV technology [4]. With virtual network functions (NFV), the network can react in a more agile manner as the

Manuscript received January 5, 2017
Manuscript revised January 20, 2017

municipality requires. This is particularly important because the network underlying the smart city must be able to extract high levels of contextual insight through real-time analytics conducted on extremely large datasets if systems are to be able to problem-solve in real-time; for example, automatically diverting traffic away from a street where a traffic incident has taken place.

Moreover, existing mobile terminals are generally equipped with multiple network interfaces, typically WiFi and cellular. This, together with the proliferation of femtocells, WiFi hotspots, and WiFi access to fixed residential home gateways, has complicated the process of selecting the best access technology at each moment. For example, the 3GPP EPS Network Architecture [5] shown in Figure1 is comprised of a collection of networked dedicated hardware appliances. By using NVF solution, an API could be offered to the service providers so they can influence the decision of which access technology is used to deliver a certain type of traffic to a specific mobile terminal or group of users.

B. CAMELO View

As shown in Figure 2, we propose to integrate new modules inside the MANO framework to help cities converge disparate communications networks run by various government agencies, to delivers seamless connectivity. Using a Multi-Ran coordinator and a decentralized control inside the NFVI block can yield a more agile service provision process by dynamically defining the network that connects the IoT end devices to back-end data centers or cloud services

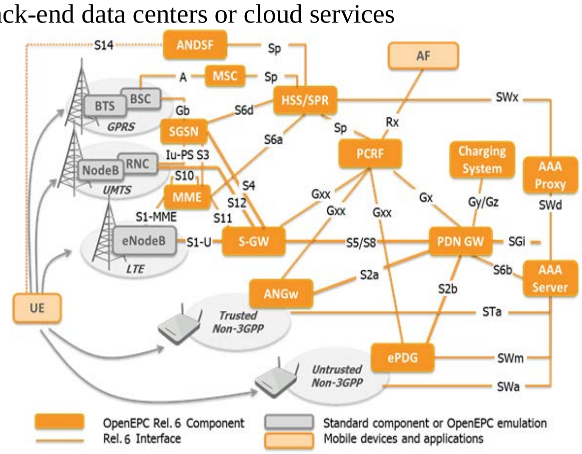

Figure 1: 3GPP EPS Network Architecture

The ETSI MANO framework offers the management and orchestration needs for the NFV architecture through three functional layers:

- Virtualized Infrastructure Managers (VIMs): This layer handles the virtualization of physical hardware in the data center by integrating with virtual-machine managers. Using a hypervisor, the virtual-machine manager provides the ability to create multiple virtual compute, network, and storage elements. The virtual machines provide lifecycle management functions (create, edit, delete, start, and stop) for the virtual data center elements related to compute, network, and storage functions.

- VNF Managers (VNFMs): The VNF managers handle the configuration, lifecycle management, and element management of the virtualized network functions.

- NFV Orchestrator (NFVO): The orchestrator provides lifecycle management of the network services that includes instantiation, scale-out/-in (called elastic scaling), performance measurements, event correlation, resource management, validation and authorization for resource requests, and policy management.

The VIM and VNFM layers together provide the VNF and resource lifecycle management capabilities. The NFVO provides the lifecycle management around the virtualized network service.

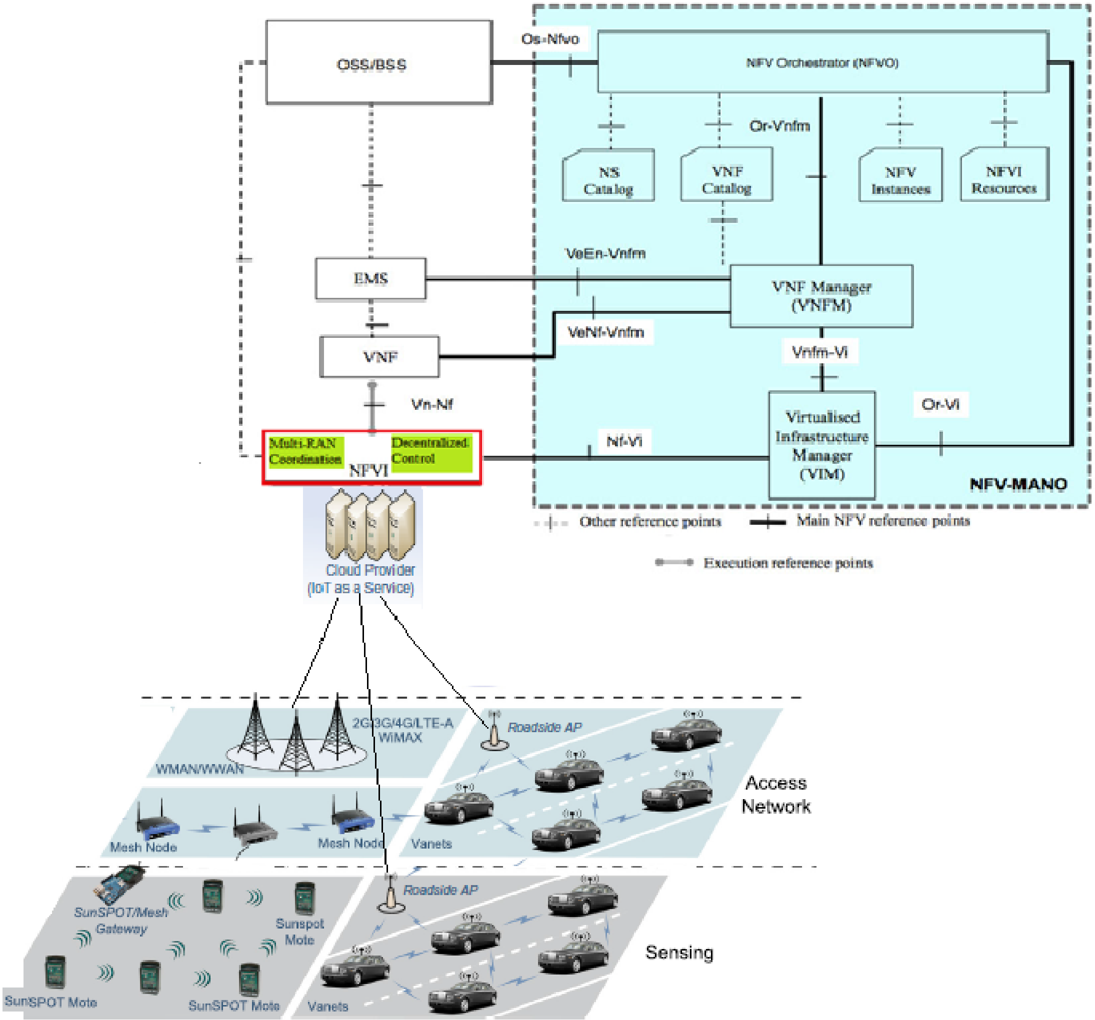

Figure 2. Cloud-based Architecture for the smart City

C. *Smart cities applications*

The user of a cloud service has access to the service through a Web interface or via an API. Once started, the cloud service application acts as if it is a normal desktop application.

3. USE CASE: Unified Mobility Method through Heterogenous RAN

We implement the unified mobility functionality inside the Multi-RAN Coordinator and the decentralize control block as shown in Figure 3.

The essence of the smart city is the convergence of multi-RAN technologies. An efficient and general control solution for 2G/3G/LTE/WiFi operations is needed for the deployment of smart cities applications. A common control plane optimization regarding Multi-RAN resources management and seemless mobility is thus necessary.

We will present in this section, how an intelligent wireless networks selection for cloud access can be implemented based on the presented CAMELO framework.

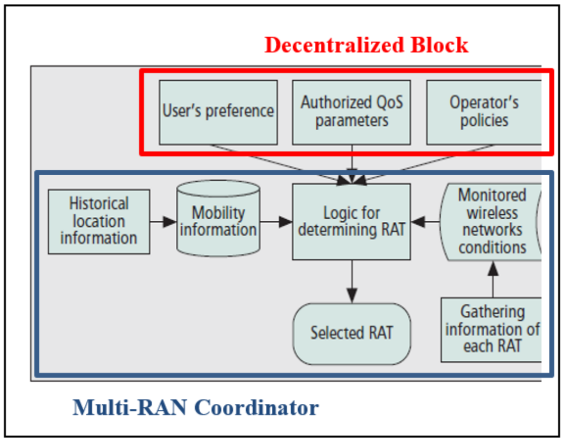

Figure 3: Mobility management Method

One of the key issues encountered in a mobile cloud is the design of intelligent mobility management techniques that support user mobility while providing a seamless service. Using 'Intelligent access' for Mobile Cloud Computing is important, because the use of context information provided by terminals, network nodes, or sensors deployed in the users environment enables efficient network access management across different Radio Access Technologies.

To offer an efficient context-aware solution at the access network selection stage, we need to interact with the decentralized block (Figure 3) to get more fresh information from the application and user side (i.e. user preferences, service capabilities, battery status …) as well as from the access network side (i.e. QoS parameters, cost). The most appropriate wireless network, from those available, has to be selected satisfying a number of objectives.

We consider a Multiple Objective Decision Making method [6] in which all available alternatives (wireless access networks) are evaluated according to some objectives. We choose to base our decision on 4 criteria:

1. *Security level*: three levels of security are considered; high for very secure link, then medium and finally low level for open access.
2. Low *delay*: end-to-end delay on the wireless access link
3. *Power* consumption: to meet nowadays requirements for green networks, we choose the access network with less power consumption.
4. Maximize *link Bandwidth*

We base our work on the AHP method, developed by Saaty [7]. It addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem. The process makes it possible to incorporate judgments on intangible qualitative criteria alongside tangible quantitative criteria.
AHP has been selected because the ability to create various weights between each target. It is allowed the system to solve complex problem by instructing ideas hierarchically and then perform the paired comparison of the elements. Decision making parameters have been considered such as network conditions (bandwidth, delay, security and energy saving) and user preferences in services (applications in real time and non real). Based on priorities by users, scores between 1 to 9 are assigned, while score 1 with the highest preference and the lowest is 9.

Three steps have to be performed:

1. *The Criteria Scoring* is a pre-configuration step in which the importance of each objective metric is evaluated according to user preferences.
2. Then, *the Radio Access Network scoring:* the available access networks are evaluated according to information from the context-aware data-base and compared according to application's QoS or user objectives.
3. *Decision*: Finally, the CAMELO architecture has to select the best access network according to the comparison matrix (section III.C).

D. Criteria Scoring

Based on the priorities given by the user, scores between 1 and 9 are assigned automatically, where 1 is the most preferred criteria and 9 the least preferred one. The scores are equal-spaced integers whose space-gap is defined by:

(1)

$$I = (S_h - S_l)/Np$$

$$S_{i+1} = S_i + I$$

Where Np is the number of parameters, S_h and S_l are the highest and the lowest possible scores (i.e. 9 and 1) respectively, and I is the numeric space-gap between two subsequent scores.

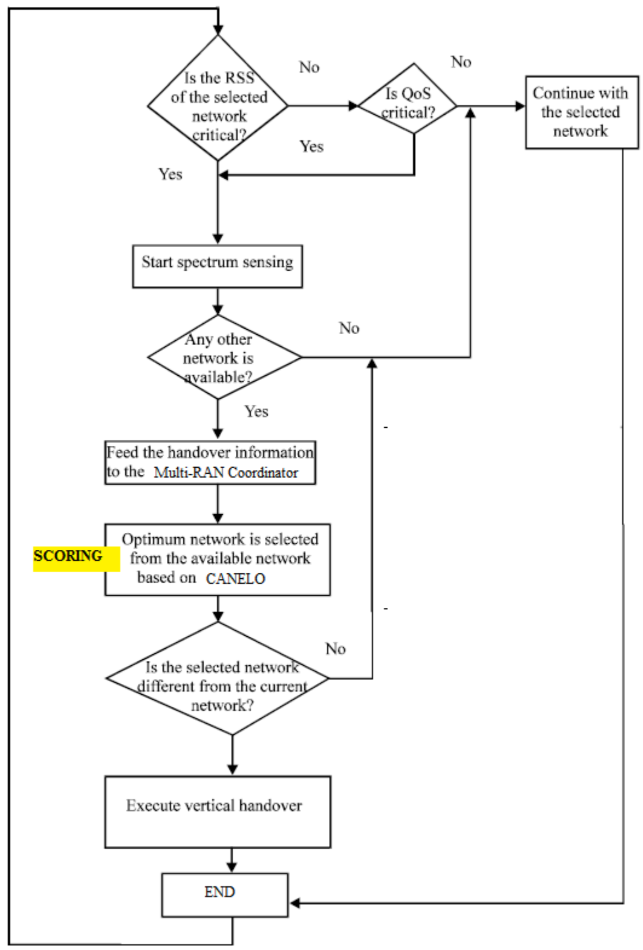

Figure 4: Vertical Handover Execution

E. Access network Scoring

Here, scores have to be assigned to each of the available access radio network based on user preferences. To evaluate these QoS Scores, we adopt the technique described in [8].

Quality scores are then calculated as follows:

$$Si = \left(1 - \frac{ni - li}{ui - li}\right) * 10, \; if \; li > ni > ui \qquad (2)$$

$$Si = \left(\frac{ni - li}{ui - li}\right) * 10, \; if \; li < ni < ui \qquad (3)$$

$$Si = 1, \; ni \geq ui$$

$$Si = 9, \; ni \leq li$$

Where u_i and l_i are, respectively, upper and lower limits for a particular QoS parameter, and n_i is the value offered by a network for that parameter.

F. The vertical mobility Decision:

It's the final step of the selection algorithm. CAMELO calculates the final decision. The Analytic Hierarchy Process (AHP) [4] is used. It deals with problems which involve the consideration of multiple criteria simultaneously. It is unique in its ability to deal with intangible attributes and to monitor the consistency with which a decision maker makes his decisions.

The steps of AHP are as follows:

- Calculating the pairwise comparison matrix A based on Objective Scores calculated in section III.B.

(4)

$$A = \begin{pmatrix} 1 & \cdots & RS1n \\ \vdots & \ddots & \vdots \\ \frac{1}{RS1n} & \cdots & 1 \end{pmatrix}$$

Where:

$$\frac{1}{RSij} = \left(1 - \frac{Si}{Sj}\right) * 10, \qquad Si > Sj$$

$$RSij = \left(1 - \frac{Sj}{Si}\right) * 10, \qquad Si < Sj$$

Then, we develop the normalized matrix ***A'*** (Equation 5):

(5)

$$a'ij = \frac{aij}{\sum_{k=1}^{n} akj}$$

Then we obtain the priority vector P related to objectives by:

(6)

$$P_k = Avg\ (k^{th}\ row\ of\ A')$$

- Determining the RAN scores and selects the access network with the highest sum.

(7)

$$Score\ RAN\ i = \sum_{1}^{ij} Wnij\ woj$$

4. Performance results

Some simulations were conducted under OMNET++ simulator. In our design, we have considered the availability of the wireless network depends on the received signal strength. If RSS is below the threshold, the RAN is unavailable. The Handoff decision is made following the steps of the previous section. Network with highest score is the selected network. Interaction with MATLAB is needed to evaluate scores.

Table 1: Simulations caracteristics

Characteristic	WiFi	UMTS	LTE
Coverage Size	50 m - 100 m	1000 m	500 m - 1000 m
Trigger Link Down factor	1.2	not used	not used
PHY model	Two-Ray Ground Model	Ray Tracing Model	OFDMA/MIMO/
Antenna Type	OmniAntenna	OmniAntenna	OmniAntenna
Frequency Range	2.4 Ghz	1.8 Ghz	2 Ghz
RX Threshold	5.2×10^{-10} W	1.0×10^{-16} W	1.0×10^{-16} W
Peak Data Rate	11 Mbps	384 Kbps	100 Mbps

We consider the three RAN networks in the smart city scenario as RANs for the city cloud: WIFI UMTS and LTE. We get the relative scores of each objective (see Table 1).

Table 2: Objectives scores assignements

Criteria		wj	Membership Values		
			UMTS	WiFi	LTe
RSSI	c_1	0.0181	0.8125	0.8945	0.9110
Data Rate	c_2	0.4772	0.0994	0.9000	0.9000
Network Latency	c_3	0.1198	0.5949	0.7839	0.8865
Security	c_4	0.0181	0.8985	0.8938	0.8993
Power Requirement	c_5	0.00181	0.7998	0.7484	0.6552
Mobile Velocity	c_6	0.0385	0.8972	0.5000	0.5000
Service Cost	c_7	0.2202	0.5982	0.8300	0.8500

Although various vertical handoff algorithms are proposed in the literature, some problems remain unsolved. Some tend to adopt a simple decision algorithm to maintain a faster handoff procedure. But the simple decision making mechanism may not help to select a suitable network and may also yield serious Ping-Pong effect. Others regard the handoff decision procedure as a multiple attribute decision making problem [10-12] and tend to solve the problem by searching for the optimal solution from the mobile perception. These algorithms are not adapted for the mobile could because they neglect the evaluation of the whole wireless environment, which may cause the unbalanced loads distribution. We compare the performance of our proposed CAMELO with another classical vertical handoff algorithm [12].

Deciding in the correct time to initiate a handover can reduce the subsequent handovers; limit the delays (Figures 5-6) and can predict also disconnections during Mobile's movement.

Selecting the best access network can satisfy user requirements anywhere and anytime in a flexible (using policies) and efficient (advanced decision mechanisms) manner. Thus, it should prepare the control mechanism (i.e. handover execution phase) and participate to provide performance optimization such as a seamless handover (minimum handover latency and packet loss)

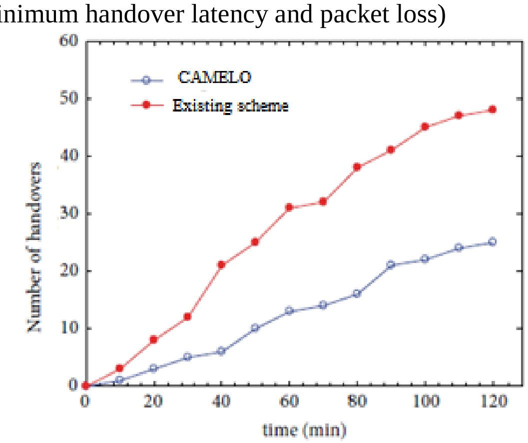

Figure 5: Number of vertical handover

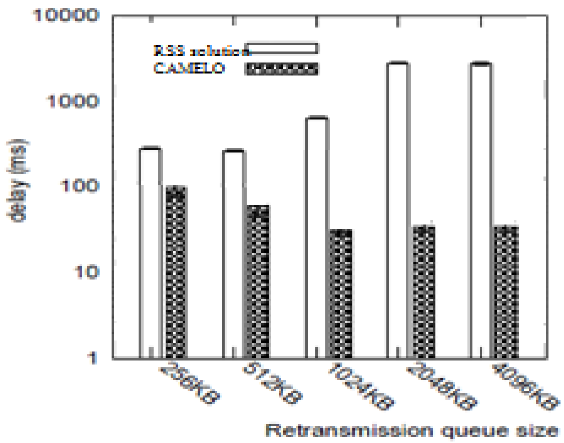

Figure 6. CAMELO end-to-end delay

5. Conclusion

In this paper, a context-aware mobile cloud computing framework architecture is presented. We started by exposing the mobile cloud computing paradigm and NFV functionality ; then, explaining our mobile cloud smart city framework named « CAMELO ». Afterward, we presented a user case on heterogeneous wireless network selection. Future works will concern the choice of adequate algorithm for offloading in the CAMELO architecture.

References

[1] P. Makris, D. N. Skoutas and C.Skianis, “A Survey on Context-Aware Mobile and Wireless Networking: On Networking and Computing Environments’ Integration,” IEEE communications surveys & tutorials, vol. 15, no.1, Quarter 2013.
[2] L. Lei and Z. Zhong, K. Zheng, J. Chen and H.Meng. “Challenges on wireless heterogeneous networks for mobile cloud computing,” IEEE Wireless Communications, June 2013.
[3] MANO, ETSI NFV ISG, “ETSI Network Functions Virtualisation (NFV) Industry Standards (ISG) Group Draft Specifications,” http://docbox.etsi.org/ISG/NFV/Open, December 2014, Accessed on May 26, 2015.
[4] R. Mijumbi, J. Serrat, J. Gorricho, N. Bouten, F. De Turck, and R. Boutaba, “Network function virtualization: State-of-the-art and research challenges,” Communications Surveys Tutorials, IEEE, vol. PP, no. 99, p. 1–1, 2015.3GPP
[5] Hwang, C.-L., Masud, A.S. M « Multiple Objective Decision Making — Methods and Applications, A State-of-the-Art Survey », Lecture Notes in Economics and Mathematical Systems, book 2012.
[6] T. Saaty. How to Make a Decision: The Analytic Hierarchy Process. European Journal of Operational Research, 48(1):9–26, 1990
[7] E. Arun and R. S. Moni, "Optimization of Vertical Handoff Decision Algorithm for Wireless Networks," International Journal Of Computers Communications & Control , vol.7, 2012
[8] T. Ahmed, K. Kyamakya, and M. Ludwig, “A context-aware vertical handover decision algorithm for multimode mobile terminals and its performance,” IEEE/ACM EATIS 2006.
[9] Y. S. Guo, G. Z. Tan, A. Libda and L. Q. Ma, "A QoS aware vertical handoff algorithm based on predictive network information," Journal Of Central South University, vol.19, pp. 2187-2193, 2012.
[10] E. Arun and R. S. Moni, "Optimization of Vertical Handoff Decision Algorithm for Wireless Networks," International Journal Of Computers Communications & Control , vol.7, 2012.
[11] S. Lee, K. Sriram, K. Kim, Y. H. Kim and N. Golmie, "Vertical handoff decision algorithms for providing optimized performance in heterogeneous wireless networks," IEEE Transactions on Vehicular Technology, vol.58, pp. 865-881, 2009.

Aymen EL AMRAOUI received the Computer Science Engineer degree from the National School of Computer Sciences (ENSI, Tunisia); He is a Phd. student at Signal and Mechatronics Systems Research Unit (SMS) at the National School of Engineer of Carthage (ENICarthage, Tunisia); Currently working as Associate Professor of Computer Sciences at the High Institute of Technological Studies of Bizerte (ISET). His area of interest is Telecommunication and Networking, Virtualization and Cloud Computing.

Kaouthar Sethom received the B.E. degree in Telecommunication engineering from the Higher School of Telecommunication SUPCOM, Tunisia, in 2002, the Master in Telecommunication from Telecom Paris in 2003; and Ph.D. degrees from the University of Paris 6, UPMC, France, in 2006 respectively. She joined Paris 8, in 2007, as associated Professor. Since 2008, she is Professor with the National School of Engineering Carthage (ENIcarthage, Tunisia). Her main areas of research interest are wireless networks, routing, mobility management, and cloud computing.