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Intelligent network functionalities in wireless 4G networks: Integration scheme and simulation analysis

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ABSTRACT

In future wireless and mobile environments it is likely that mobile stations will be able to choose between multiple access networks offering competing services. Wireless 4G network should offer a wide use of information processing techniques, efficient manipulation of the network resources, and reuse of network functions. It should also allow the insertion of supplementary capacities making it easy to add services. In this article, first we study the design of intelligent services in wireless fourth generation networks. Then, we propose several intelligent network functionalities to determine the best network to use efficiently. Finally, we study the effect of the intelligent functions on the network performance using simulation analysis.

1. Introduction

The evolution of wireless network technologies has led to different generations of wireless cellular systems referred as *n*G (1G, 2G, 2.5G, 3G,...). Current wireless systems only provide limited services. For instance, 2G, 2.5G users are asking for communication services at the wire line quality (both voice, data, multimedia) when they are mobile. A very high-data rate is required to realize this and this data rate is well beyond the capability of the third generation (3G) wireless systems. This is the motivation behind the increasing research thrust on defining and designing wireless fourth generation (4G) networks [1–3]. The vision for 4G and beyond systems is towards unification of various mobile and wireless networks. However, there is a fundamental difference between wireless cellular and wireless data networks, such as WLANs. The difference is that cellular systems are commonly circuit-switched, meaning that for a certain call, a connection establishment has to take place prior to the call. On the contrary, wireless data networks are of packet-switched nature [4].

Fourth generation wireless networks will be a heterogeneous network consisting of different access networks, which may overlap with one another. In this environment, a mobile station is equipped with a mobile device containing multiple wireless interfaces or a multi-mode interface. It will enhance and extend mobility: anytime and anywhere accessibility, IP mobility, privacy and security of communications, diversity of services while keeping low cost. The wireless 4G networks are expected to include wireless access, wireless mobile, wireless LANs PANs, and satellite networks and to provide a wide range of services including high-speed data and real-time multimedia to mobile users. The mobile user is expected to be able to communicate through different wireless networking architectures and to roam within these architectures.

The wireless 4G networks will envision flexible and adaptive integration of network technologies to enable mobile node to seamlessly roam between access networks [1,2]. These networks should not only provide the commonly known Internet services, but also should transport the traditional voice service and other real-time applications. Eventually, they should allow more advanced broadband multimedia services with varying QoS requirements (e.g., preferred low delay, limited jitter, high throughput, or high peak packet rate). Mobility management, including, handoff, best network selection, and location management, allow multimedia applications to get certain quality guarantee on bandwidth, jitter and delay for its packets delivery [5–14].

Wireless 4G networks will not only help improving existing services [5,6] but integrate intelligent algorithms for mobility management, resource management, access control, routing, etc. They will offer a wide use of information processing techniques, an efficient manipulation of the network resources, and reuse of network functions. They should allow the insertion of supplementary capacities making it easy to add services.

In public telephone networks, the experience realized with the integration of intelligent services has shown its advantages and success. The situation is now taking place with wireless second and third generation networks [6]. Complementary services make

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the management of the wireless 4G networks easier, and provide flexible access to multimedia applications. To the best of our knowledge, very few works have dealt with wireless intelligent networks. The Third Generation Partenership Project 2 (3GPP2) [6] has started taking interest in intelligent network in wireless networks. It has just focused on defining the wireless intelligent network architecture in terms of functional entities.

Our contribution in this article is 2-fold. First, we define an architecture for heterogeneous Wireless 4G networks that makes the composing access networks transparent to users and provides seamless services. Second, we propose the introduction of complementary services and intelligent network functionalities, such as best network selection, handoff and location management, in wireless fourth generation, showing their effects and behaviors.

The remaining part of this article is organized as follows. Section 2 describes the wireless 4G, requirements and characteristics. Section 3 introduces some complementary services. Section 4 gives the design of some services that we find useful for multiple advanced applications. Section 5 describes and analyzes the performance results obtained from the simulation analysis. Finally, the conclusion is presented in Section 6.

2. Wireless fourth generation

The fourth generation wireless networks will envision flexible and adaptive integration of network technologies to enable mobile node to seamlessly roam between access networks [7,8]. These networks should not only provide the commonly known Internet services, but also should transport the traditional voice service and other real-time applications. Eventually, they should allow more advanced broadband multimedia services with varying Quality of Service (QoS) requirements (e.g., preferred low handoff delay, high bandwidth utilization, or low packet loss rate). It also can use high-altitude platforms (HAPs) as they will have an important role to play in future systems and applications. HAPs have the potential to exploit many of the best aspects of terrestrial and satellite-based systems (LEO, GEO), while offering advantageous propagation characteristics. Such platforms may be airships or aircraft and for environmental considerations would ideally be solar powered [15,16].

2.1. Fourth generation requirements

The main objectives of 4G wireless networks can be stated as having ubiquity, and multi-service platform, with secured access and traffic. Wireless 4G service quality will be the collective effect of the performance of all system elements in combination with the user expectations, which determines the degree of satisfaction of the 4G users. The main requirements are shown below:

- *Seamless access.* Seamless access in wireless 4G network will mean connectivity to the end user across a wide range of heterogeneous access technologies and access networks using different technologies with minimal involvement from the user.
- *Low handoff delay and loss rate.* Handoff introduces packet loss and delay which can severely damage data communications. Handoff mechanisms must therefore be managed to minimize these aspects and maintain a good network performance (no disruption to user traffic, minimal additional signaling, and low packet loss rate).
- *Multi-service network.* A multi-service network is an essential property of the new wireless generation, not only because it is the main reason for user transition, but also because it will give telecommunication operators access to new levels of traffic. Voice will loose its weight in the overall user bill with the raise of more and more data services. The wireless 4G network will offer unlimited mobility and support high-data rate, services with variable bandwidths, symmetrical and asymmetrical data transfer (e.g., voice, video, fax, Internet services). This broad array of services will be provided to mobile users by supporting load balancing, priorities and guaranteed quality of service classes.
- *Broadband wireless access networks.* 4G network need to integrate means of delivering multimedia communications to metropolitan areas using High-Altitude Platform (HAP) systems or/and satellite systems. In many ways, HAPs are equivalent to satellite systems except that they are much cheaper and they can easily be redeployed and/or maintained.
- *Security access and traffic.* To attain the success of wireless 4G network, these systems must address security issues properly and integrate strong cryptographic schemes into the system.

2.2. Model of wireless fourth generation

The basic goals of the wireless 4G networks are to make the heterogeneous network transparent to users and to design a system architecture that is independent of the wireless access technology. There are several architectures using multiple different radio access networks (RANs) [3,?]. The main models are tunneled networks, hybrid networks, and heterogeneous networks. The distinction between these models is in the layer on which the RANs communicate.

2.2.1. Tunneled networks

In this model, a user has a service agreement with the operators of several RANs independently. Based on a certain policy, the optimal network for the requested service is selected. The connectivity between networks is based on relatively high network layers of the Internet (i.e., transport or session layers). This will require no modification to existing access networks.

2.2.2. Hybrid networks

In this model, we have a hybrid core that interfaces directly between RANs and the IP backbone. In this model, RANs implement the network layer and the layers below.

2.2.3. Heterogeneous networks

In this model, there is a common core network that deals with all network functionality and operates as a single network. Different RANs handle only those tasks that are specifically related to a certain radio access technology. In general, wireless access radio incorporates the physical and the data link layers only. Communication between RANs belonging to the same common core network is based on lower network layers (link layer or network layer). This reduces the overhead, and improves the network performance.

In our work, we choose the hybrid model. In fact, the advantages of this model include fewer duplicate functions and more advanced services at the network or data link layer (e.g., it can provide a better handoff between RANs). In the tunnel model, the connectivity between networks increases the service latency. Moreover, all the networks have their own infrastructure (e.g., signaling, network discovery, handoff, etc.) This makes it very difficult for existing network systems to cooperate efficiently. The proposed network architecture for wireless 4G network is illustrated in Fig. 1 [9].

The basic architecture of the wireless fourth generation network is divided into fourth levels. Lower levels are comprised of high bandwidth wireless cells that cover a relatively small area connection over a larger geographic area. Also, the networks of