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## Computer Networks

journal homepage: [www.elsevier.com/locate/comnet](http://www.elsevier.com/locate/comnet)

## Virtualization architecture using the ID/Locator split concept for Future Wireless Networks (FWNs)

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## ARTICLE INFO

## Article history:

Available online 22 September 2010

## Keywords:

ID/Locator split  
 Future Wireless Networks  
 FWNs  
 Next generation wireless networks  
 NGWNs  
 Mobility  
 Multihoming  
 Privacy  
 System Architecture Evolution  
 SAE  
 Virtual object  
 Object  
 Virtual object to virtual object  
 communication  
 Virtual channel  
 Channel  
 Multi-tier  
 Future wireless internet  
 Future internet  
 Network architecture

## ABSTRACT

Future Wireless Networks (FWNs) will be a convergence of many fixed and mobile networking technologies including cellular, wireless LANs, and traditional wired networks. This united ubiquitous network will consist of billions of networkable devices with different networking interfaces. A common networking protocol is required to communicate among these devices and interfaces; System Architecture Evolution (SAE) documents state that Internet Protocol (IP), world-widely used in the current Internet, is likely to become that common protocol. However, traditional IP architecture has faced several known challenges, such as mobility, multihoming, privacy, path preference selection, etc., which should be resolved in FWNs. One of the difficulties in the current IP architecture is the overloading of IP addresses used both as the identity and the location of IP devices. In this paper, we propose a virtualization concept for networkable components, or (*virtual*) *objects*, which generalizes all abstract components to potentially be used in FWNs. In addition, we have explicitly separated the functions of the virtual object identity from the virtual object location (using the ID/locator split concept). The end-to-end communication is a *concatenation* of the involved components, called a *channel*. To help support the ownership and policy enforcement for trusted vs. untrusted networks, a set of (virtual) networkable components with the same interest, called a *realm*, is formed in a multi-tier structure. The individual policy can be enforced for each individual group of (virtual) objects and/or channels. This virtualization architecture concept, characterized by the ID/locator split concept, is well-suited for FWNs and helps eliminate problems in the current Internet.

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### 1. Introduction

Future Wireless Networks (FWNs) offer a large-scale *interoperability* of diverse traditional wireless networks with many types of wireless technologies: cellular networks, sensor networks, RFID (Radio-Frequency Identification) networks, and the conventional wired networks. FWNs are evolving into an ubiquitous network in which customers or users will not need to be aware of the differ-

ent behaviours and/or characteristics of the networking media underneath their applications [1]. Moreover, a policy-based control would be necessary to make use of multiple interfaces [2–5] in an efficient way.

FWNs should also support peer-to-peer, point-to-multi-point, and ad hoc infrastructure modes. FWNs may provide a *guaranteed service* with an agreement on the quality of service (QoS) control, as well as best-effort services. In addition, the emergence of billions of networkable mobile wireless devices, which may outnumber the wired PC's as early as 2010 [4], including Laptops, PDAs (Personal Digital Assistants), cell phones, wireless sensors, etc., shall exacerbate the problem of *scalability* in the current networks.

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Moreover, with the advances in networking technologies, the concept of a single user-single host-single interface will no longer be common in FWNs. Users bearing several multi-interface wireless devices leveraging a variety of networking interfaces, such as wireless local area networks (WLANs), 2G/3G, LTE (Long Term Evolution), (Mobile) WiMAX, and Ethernet shall call for an ubiquitous high-speed networking environment that can inherently support *mobility*: mobility over large geographic topologies and mobility of users (mobile users) over devices, device *multihoming* and concurrent multi-interface sessions.

With various networking connections, service providers and mobile users should be able to choose the best connection (*path preference selection*) based on cost and quality of service (QoS) requirements. Multiple interfaces should allow load sharing, load balancing, and higher availability with recommended path information from the service providers. Also, the mobile users should be able to maintain their *privacy*, while the networking environment should provide inherent *security*. Apart from all these requirements, FWNs' designers also need to evaluate the transition steps from the current networks to FWNs, e.g., how to incrementally *deploy* the FWN system into the current network [6–9].

The issues of interoperability, guaranteed service, scalability, mobility, multihoming, path preference selection, privacy, security, deployability, etc., discussed above, represent some of the key requirements for the design of FWNs. Given these different sets of requirements, it is quite difficult to predict which direction FWNs will be headed, especially in terms of a common communication protocol among networking components. The 3rd Generation Partnership Project (3GPP) has made a decision to adopt Internet Protocol, or IP [10,11], into cellular networks as well. System Architecture Evolution (SAE) is the core networking architecture being developed by 3GPP [12–14] for the next generation of cellular wireless networks. SAE will be an *all-IP based mobile wireless network*.

Note that FWNs will face the same problems that have been identified for the current Internet. The Internet now is not only being used academically, but also in industry with a non-trustworthy design for commercial applications. So, this design has brought difficulties into the relationship amongst the organizations and the administrative hierarchies. More importantly, one of the greatest issues of the current IP architecture is *the overloading of IP address semantics* [15–19]. The IP address acts as a host or node identifier as well as a locator in the routing space. This contextual overloading implicitly binds a host to its point-of-attachment in the network, and there is no independent namespace to represent the end host itself. Thus, every time the end host moves to a new network or changes its interface; and consequently obtains a new IP address, all the sessions bound to the previous IP address are broken.

Such an implicit overloading makes it difficult to support full mobility, multihoming, traffic engineering, privacy, security, etc. As a result, in this paper, we propose a new concept on how to apply the ID/locator split idea into the IP-based FWNs. In addition, we extend this splitting

concept beyond hosts in order to be general enough to cover all feasible physical and logical components, or *objects*, in FWNs. We call this the *virtualization of objects*.

Note that in this paper, we do not intend to limit the architecture to a specific solution, but rather provide the virtualization architecture concept in general. Obviously, there are possible solutions available; some may meet the requirements, and some may not. Nevertheless, we include some probable techniques when we introduce the architecture requirements.

This paper is organized as follows. In Section 2, we discuss common terminologies in the traditional network architecture. In this section, we compare an illustration of a wired/wireless and cellular network structure. Also, we briefly explain a cross-over function among these terminologies. In Section 3, we discuss the proposal of an ID/locator split concept that will apply to the virtual networkable components in FWNs. Using examples, we illustrate how to apply the FWN architecture concepts to our current network in Section 4. In Section 5, we show feasibility by applying the ID/locator split concept into our virtualization architecture. In Section 6, we briefly describe related work focusing on the ID/locator split concept proposed in the current IP networks. We also briefly point out their pros and cons which leads to our proposal. Finally, our conclusions are drawn in Section 7.

## 2. Current networks: terminology and system architecture

This section describes terminologies used in current networks. We also discuss a conceptual definition for each term and notation with provided examples. In addition, we discuss two main current network architectures illustrated by examples: wired/wireless data networks (Internet) and cellular networks.

### 2.1. Terminology

*Name*: a word or a combination of words, readable and recognizable by humans, to identify a person, place, or thing, such as *John Smith, Washington University in St. Louis, Intel, and Microsoft*. Usually, *name* is also represented by the organizational management, which tends to be hierarchical; for example, *john.smith.cec.eng.wustl.edu* represents user John Smith in the Department of Computer Science and Engineering, School of Engineering and Applied Science, Washington University in St. Louis.

*Address*: a point of attachment or the name of the place where a person, something, or organization may normally be reached; for example, *One Brookings Drive, St. Louis, MO 63130 USA* is the address of Washington University in St. Louis.

*Locator*: where something could be located currently, such as GPS (Global Positioning System) latitude and longitude positions. Note that the address and the locator are very similar, and in some contexts they are the same. For instance, *One Brookings Drive, St. Louis, MO 63130* and GPS positions at  $38^{\circ} 38' 52.82''N$  and  $90^{\circ} 18'16.22''W$  are considered as both the address and the locator. However,

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