Performance Evaluation 102 (2016) 21–33

Contents lists available at ScienceDirect

Performance Evaluation

journal homepage: www.elsevier.com/locate/peva

Dominant handover algorithms for vehicular Radio-over-Fiber networks at 60 GHz: A performance evaluation study

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ARTICLE INFO

Article history:
Received 7 February 2015
Received in revised form 8 May 2016
Accepted 23 May 2016
Available online 8 June 2016

Keywords:
Handover algorithms
Vehicular Radio-over-Fiber networks
Performance evaluation
Mathematical model
Simulation scenarios

ABSTRACT

In mobile picocellular network topologies a critical issue is the handover procedure in conjunction with the provided quality of service, due to the limited overlapping areas between adjacent cells. In vehicular picocellular networks handovers are more frequent and render quality of service metrics – such as packet loss rate, delay and jitter – even more critical, since the afore-mentioned limitation is combined with the high velocities of mobile end-users.

The paper focuses on presenting the dominant handover algorithms in vehicular Radio-over-Fiber (RoF) networks at 60 GHz, i.e., the Traditional Handover Algorithm (THO), the Virtual Cellular Zone (VCZ), the Moving Extended Cell (MEC) and the Moving Extended N-Cells (MENC), respectively. Furthermore, we present a performance evaluation study on the provided quality of service for all the afore-mentioned handover algorithms. Specifically, for all four handover algorithms the corresponding theoretical mathematical models regarding packet losses are analyzed. Moreover, a simulation study is realized, in order to verify the theoretical results and to present algorithms' effect on additional quality of service indicators, i.e., delay and jitter. The presented results of our performance evaluation study could be a valuable tool to network operators that plan to provide bandwidth-voracious services by deploying vehicular RoF network at 60 GHz.

1. Introduction

Some years ago, bandwidth-demanding services were mainly applicable to fixed users or to users with limited mobility. On the other hand, the broadband acceleration both for fixed and wireless network operators in conjunction with the evolution of smartphones rendered users to demand the same bandwidth-voracious services – such as video conferencing, triple-play services, HDTV, social networking, rich media file sharing in the cloud, to name a few – even on the go. Users in trains or cars and especially in public transportation's vehicles, tend, or at least require, to use their devices as at their home's network, which is usually a combination of fixed technologies like xDSL, VDSL2, FTTx, xPONs, etc., with IEEE 802.11b/g/n, 60 GHz or other wireless access technologies.

In vehicular networks and specifically in vehicle-to-infrastructure (V2I) architectures several wireless access technologies are exploited, such as 3G, WiMAX, LTE or WLAN [1]. Another communication paradigm that recently attracts high attention is the use of Radio-over-Fiber (RoF) network architectures at 60 GHz for delivering broadband wireless

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http://dx.doi.org/10.1016/j.peva.2016.05.001
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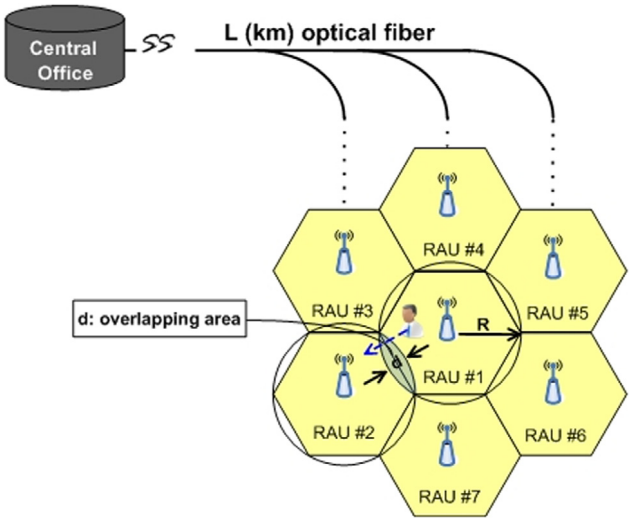

Fig. 1. The Traditional Handover Algorithm (THO).

access services, which combine the strengths of fixed optical and mobile millimeter-waveband technologies [2–4]. A strong advantage of the afore-mentioned architectures is their basis. RoF at 60 GHz architectures are based on the combination of low cost and low complexity Remote Antenna Units (RAUs) located in remote sites in order to support the communication with the mobile end users, and on an intelligent and centralized unit, named Central Office (CO), which aggregates the entire network functionality and has the responsibility to handle and execute complex signal processing and render passively the communication with RAUs. Several studies have adopt the RoF@60 GHz approach [4–6], while the first results prove the effectiveness of 60 GHz RoF networks on supporting Gbps data rates in both indoor [6–9] and outdoor [10,11] environments.

On the other hand, RoF networks at 60 GHz have to overcome several innate limitations of the 60 GHz frequency band, in order to ensure a seamless mobile communication environment, and the handover procedure is one of them [2,12]. Handover is the required process in wireless mobile cellular networks allowing end users to move from one network cell to another transparently to the network without loss or interruption of the end-user service. In RoF at 60 GHz networks, the typical handover algorithms become ineffective as the strong air-propagation losses of the 60 GHz signals restrict cell radii to a few tens of meters yielding inevitably to picocellular configurations with small overlapping areas between neighboring cells. In outdoor environments, the radius (R) of a picocell in 60 GHz RoF networks fluctuates between 15 and 20 m, which results to an overlapping area (d) of 4–5 m in the best case, as depicted in Fig. 1. Thus, in outdoor environments, the handover problem aggravates in vehicular networks, in which the end users' velocities are even higher [13]. A thorough survey on handover algorithms regarding several wireless mobile cellular networks, including GSM, UMTS, WLAN, LTE, Mobile WiMAX as well as 60 GHz based systems can be found in [12], while our initial, indicative performance results regarding two different handover techniques in RoF vehicular networks at 60 GHz are available in [13].

In this paper we focus on outdoor environments serving end-users with high mobility and we present a performance evaluation study on the dominant handover algorithms applied in vehicular RoF networks at 60 GHz. The rest of the paper is organized as follows: Section 2 describes the dominant handover algorithms at vehicular RoF networks at 60 GHz. Section 3 presents and analyzes the mathematical models regarding packet loss for all the handover algorithms presented in Section 2. Section 4 describes the simulation testbed and provides the required details regarding the corresponding simulation scenarios used to verify the mathematical analysis presented in Section 3. Furthermore, the analytical and simulation results regarding packet loss are thoroughly presented and evaluated. A further discussion regarding other performance indicators, i.e., the frequency of beacon signal in RAUs and the packet delay and jitter, is also presented and evaluated in Section 4, while the paper concludes in Section 5.

2. Handover algorithms in vehicular RoF networks at 60 GHz

In this section we present the handover algorithms which can be applied in vehicular RoF networks at 60 GHz. First of all we analyze the Traditional Handover Algorithm (THO), to make clear to the reader that it cannot be applied in vehicular RoF networks, due to the high end-users' velocity. Furthermore, we present and analyze the dominant handover algorithms and schemes targeting to support high mobility to end-users in vehicular 60 GHz RoF networks, such as in railways and in highways, i.e., the Virtual Cellular Zone (VCZ), the Moving Extended Cell (MEC) and the Moving Extended N-Cells (MENC), respectively.