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Femtolet: A novel fifth generation network device for green mobile cloud computing

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ABSTRACT

For the first time, this paper proposes a new network device denoted as 'Femtolet' for fifth generation mobile network to provide communication and computation offloading facilities simultaneously at low power and low latency. The features of two separate devices femtocell base station and cloudlet are combined into a single network device denoted as Femtolet to provide the services of femtocell along with a cloud environment at low power and low latency. The architecture and working principle of the proposed device Femtolet are discussed with its power consumption model and latency. Mathematical analyses present that using Femtolet instead of the existing femtocell plus cloudlet and Small Cell cloud-enhanced e-node B architectures, power consumption can be reduced by approximately 17% and 11% respectively. Mathematical analyses also show that the proposed device Femtolet can reduce the latency by approximately 20% and 13% than the existing femtocell plus cloudlet and Small Cell cloud-enhanced e-node B architectures respectively. The proposed working model of Femtolet is simulated using Qualnet7 and its performance is analyzed with respect to average delay, average jitter, energy consumption in transmit and received modes, carried load, throughput, offloading time and offloading power.

1. Introduction

According to Cooper's law the number of voice or data conversations conducted in all radio spectrum on a given region doubles every 2.5 years.[1] Cooper's law is pictorially demonstrated in Fig. 1. With this exponential growth in the number of mobile users, network densification, power efficiency and low latency have become critical issues in the area of fifth generation mobile network [1–3]. Fifth generation (5G) mobile network has to offer high signal strength and high data rate at the same time. To provide high signal strength especially at indoor region, the femtocell technology has been developed as home node base station (HNB) [4–7]. On the other hand the demands of mobile web users to run heavier applications are increasing day by day. But the mobile phone faces some difficulties like small storage space, limited processing power, limited battery life etc. To satisfy the user demands by overcoming these problems, mobile cloud computing (MCC) has been introduced as a combination of mobile computing and cloud computing [8–11]. Cloud is the combination of virtualization of large amount of resources with a distributed computing paradigm integrated with Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) [8–12]. In MCC the data processing and data storage both take

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[1] http://www.comsoc.org/ctn/will-densification-be-death-5g.

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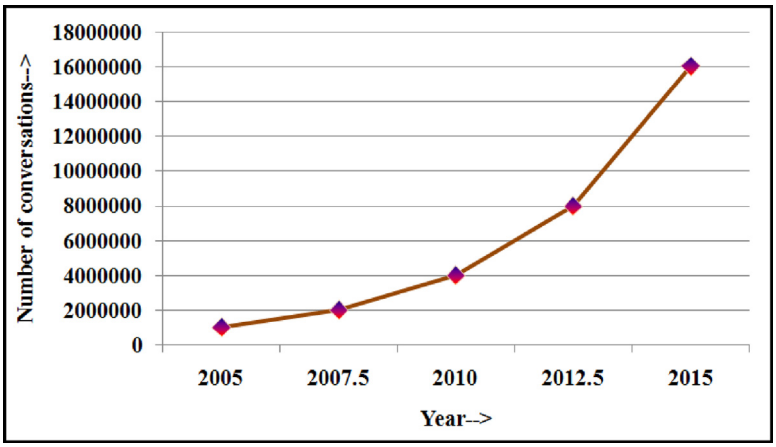

Fig. 1. Graphical representation of Cooper's law of spectral efficiency.

place outside the mobile device (MD) and into the cloud. MCC provides all the cloud services and applications like mobile commerce, mobile healthcare, mobile gaming etc. But long distance cloud access affects the quality of experience (QoE) of the users by increasing the wireless area network (WAN) delay. To provide high bandwidth wireless access to the cloud, cloudlet is introduced in the network [13,14].

A cloudlet is a reliable, resource-rich computer or number of computers connected to the Internet and accessible to the nearby MDs. It contains cache copies of the data already available inside the cloud. Accessing cloudlet through femtocell provides low latency but high bandwidth and secure wireless access [4,9]. To fulfill the aim of 5G mobile network, Small Cell cloud-enhanced e-node B (SCceNB) is introduced which provides communication with additional computation facility [15–17]. These small cell nodes are connected with a small cloud which is referred as femtocloud. The femtocloud has an intermediate storage and computation ability. The femtocloud is connected to the core cloud. Our aim is to reduce the latency as well as power consumption even than SCceNB. Hence in this paper we have proposed a new network device denoted as 'Femtolet' for 5G mobile network.

1.1. Motivations and contributions of proposed work

In femtocloud based 5G mobile network cloud service access at low latency is achieved either using (femtocell + cloudlet) or using SCceNB scenario. Accessing the cloudlet instead of the long distance cloud provides low latency i.e. high speed Internet access. But if the cloudlet is unable to provide the required service, then the cloud is accessed. In such a case due to the communication between the femtocell and cloudlet, additional power consumption and delay are introduced. This affects the QoE. On the other hand, the SCceNB provides limited cloud functionalities. If the SCceNB is unable to satisfy the user's demand, the femtocloud serves the user. If the femtocloud is also unable to satisfy the user's need, then the cloud is accessed. As the communication takes place between the SCceNB and femtocloud, and between the femtocloud and cloud, additional power consumptions and delays are introduced. As a result the QoE gets affected. To deal with this problem, our motivation is to propose a new network device for 5G mobile network which will provide communication as well as computation at low power consumption and low latency.

The contributions of this paper are:

(i) A new network device referred as 'Femtolet' is proposed for 5G mobile network by incorporating the features of both femtocell and cloudlet. The architecture and working model of Femtolet are discussed. Femtolet can serve as a home base station like femtocell as well as can act as a cloudlet for offloading data and applications to save battery life of the MDs registered under it.

(ii) The proposed network device denoted as Femtolet provides:
- Power saving with respect to the existing (femtocell + cloudlet) and SCceNB scenarios.
- Latency reduction with respect to the existing (femtocell + cloudlet) and SCceNB scenarios.

1.2. Organization of paper

This paper is organized as follows: Section 2 presents the related works, Section 3 describes the architecture and working principle of proposed network device denoted as Femtolet; the power and latency consumption models of Femtolet are developed in Section 4; performance analysis of Femtolet is discussed in Section 5; the research challenges for Femtolet are discussed in Section 6; finally conclusion is given in Section 7.