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ScienceDirect

Computer Networks 52 (2008) 1153–1165

Computer Networks

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Cooperative mobile-to-mobile file dissemination in cellular networks within a unified radio interface ☆

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Received 13 November 2007; received in revised form 11 December 2007; accepted 18 December 2007
Available online 18 January 2008

Responsible Editor: Ian F. Akyildiz

Abstract

In this paper, a data dissemination technique is introduced for cellular networks by embedding peer-to-peer data transfer into the hierarchical architecture of UMTS (Universal Mobile Telecommunication Systems) for cooperative sharing of data among mobile terminals. Our concept is based on the uplink/downlink traffic imbalance in 3G wireless networks and clearly confirms the social principle "real egoistic behavior is to cooperate". It boosts the spectral efficiency of UMTS by enabling direct mobile-to-mobile data transfer and by dynamically allocating users to temporarily unused uplink channels. The results indicate a substantial increase in service probability and overall system throughput, as well as a significant reduction of the expected file download time.
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Keywords: Cooperative file dissemination; UMTS; Traffic imbalance; Spectral efficiency

1. Introduction and motivation

Currently the telecommunication infrastructure is characterized by a rapid growth of new high data rate fixed-line services. Such observations motivate operators of wireless networks to extend their business models by offering new data applications, such as real-time streaming, distributed video conferences, as well as downloading popular movies or music files.

One of the main problems of cellular networks is the relatively limited transmission capacity. Typically, the downlink is the potential bottleneck, since all data transmissions have to be organized by providing individual links from a base station (BS) to each user. As a result, the radio interface quickly becomes saturated, which leads to degradation or even loss of the service.

In general, services can be divided in two groups: real-time and non-real time demands. The main distinguishing factor between these service classes is their delay sensitivity. The so-called streaming class as a subgroup of the former is very delay sensitive,

☆ Parts of this work are presented at IEEE Wireless Communication & Networking Conference (WCNC) 2007, Hongkong, and at the 3rd Workshop on Resource Allocation in Wireless Networks (RAWNET) 2007, Limassol, Cyprus.

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doi:10.1016/j.comnet.2007.12.007

while the background class belongs to the latter and is delay insensitive. Although the data content of the latter service type, like digital camera images, demo versions of programs for popular handset games and mp3 files, is interesting for many users, conventional solutions for capacity utilization such as multicast or broadcast are not applicable since users may request services at different times.

Currently, there are two main concepts by which the performance of wireless systems can be enhanced: complementary networks with multi-mode mobile terminals (MT) or cooperative networks, where the same radio interface can be used for different networks. Both focus on the efficient realization of a flexible radio interface and network architecture.

The main idea behind the first approach is to exploit available technologies. By implementing several radio interfaces in one device, the network operator can provide users with a seamless connectivity to data, i.e. users can proceed to be active as they roam between networks, which is very important for real-time data session continuity.

An alternative way to support an expanding variety of data applications in the 3G of cellular radio networks is to extend their existing radio interface, thereby enabling it to support different network architectures in a dynamic way.

One of the interesting research directions is to consider the relationship between the two network concepts, client–server and peer-to-peer. The client–server system model has a centralized structure, where clients communicate only with the server and never with each other. A typical example for client–server networks is a cellular network. On the other hand, the peer-to-peer system model allows a direct communication between users in an ad hoc manner with minimum infrastructure. Each user offers both client and server functionality (e.g. fixed-line peer-to-peer Internet protocols like *BitTorrent* [1], *eDonkey* [2], etc.).

Typically, these two network approaches were considered as competing, though, given the significant support of both concepts by the industry, most recent visions tend to regard them as complementing each other. Recently, even more progressive studies are investigating the effect of the synergetic cooperation between the above mentioned networks by using a unified radio interface.

These visions are illustrated in Fig. 1, where the differences of the contending network solutions are highlighted [3].

What is the actual benefit of cooperation in wireless networks?

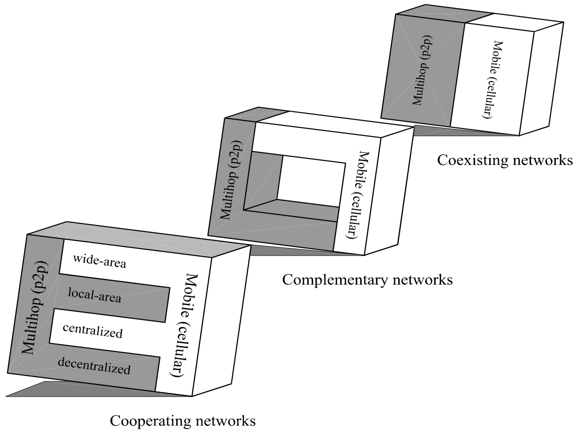

Fig. 1. Visions of the contending network solutions.

One of the primary bases for network cooperation is to fully exploit the available technologies, increase efficient usage of frequency spectrum, as well as reduce infrastructure costs.

The motivation for cooperation between cellular wireless and peer-to-peer networks is the predicted ability of peer-to-peer systems to complement conventional cellular networks in areas with poor coverage, as well as in high user density areas. Owing to direct communication between MTs, there are substantially more sender-receiver pairs than in conventional cellular networks, where the data transmission is organized by providing individual links from the base station to each user. Thus, such a hybrid network structure is capable of increasing the number of MTs that can be simultaneously handled in peer-to-peer mode.

In addition, the peer-to-peer network approach provides a further advantage. Due to the short range between MTs, the interference is expected to be lower, which leads to an increase in capacity and an improved QoS.

On the other hand, also peer-to-peer networks can benefit from the existing infrastructure of cellular networks. Peer-to-peer networks have to tolerate an increased communication traffic so that they will be able to use a decentralized structure: distributed peers generate a considerable amount of signalling traffic for coordination between them. This drawback can be mitigated by taking advantage of already existing infrastructure of cellular communication systems. For example, network operators know the location, online status and service agreement of the mobile users. They can utilize this knowledge by providing each new user with information about all active users in the system in the range of tens of meters, to deter-

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