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Smart Direct-LTE communication: An energy saving perspective

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ABSTRACT

Direct-LTE communication underlying a cellular infrastructure, or more commonly known as device to device (D2D), is discussed in this paper. When enabling D2D communication in the system, one can see several benefits compared to the conventional infrastructure based communication, such as improved energy efficiency, increased overall system throughput and decreased traffic load in the network. The aim of this paper is to give an energy efficiency perspective of D2D communication to assist all major mobile stakeholders to perceive the benefits when facilitating D2D communication in the network. This paper is tutorial in nature, initially elaborating on the fundamental concept surrounding D2D communication towards technical perspective, business opportunities and open challenges when considering deployment. Furthermore, a simulation study of a typical D2D use case is carried out that includes the energy efficiency perspective; we use 3GPP Long Term Evolution Advanced (LTE-A) as a baseline technology and candidate for launching D2D communications.

1. Introduction

Although adhoc mode has been available in 802.11 for many years, its usage has been very limited compared with infrastructure mode. Nevertheless, there has been an increased interest in device-to-device communication recently, as manifested by the WiFi Direct (WiFi-D)[1] specifications and proposals for LTE device to device standardization. The key motivation for this D2D vision is the possibility to introduce new communication patterns where we have local area connectivity. The current adhoc mode of communication does not support this seamlessly due to the configuration complexity. In this work we consider another motivation for D2D communication: it is energy efficient.

Energy efficiency has emerged as one of the most important research topics for radio systems. This leads us to develop an energy efficient mechanism which adjusts transmission power according to the traffic load and reduces the energy per bit usage. The vision of Europe 2020 is to become a smart, sustainable and inclusive economy, and as part of these priorities the EU have setforth the 20:20:20 targets where greenhouse gas emissions and energy reduction of primary use should be reduced by 20% while 20% of energy consumption should come from renewable resources. In fact, in todaýs energy conscious society, Information and Communication Technology (ICT) [1] accounts for 2% of the global CO_2 emissions. A medium sized cellular network uses as much energy as 170,000 homes [1]. While the cost of powering the existing BSs accounts for a staggering 50% of a service provider's overall expenses [1]. Therefore, new solutions are required whereby operators can accommodate additional traffic volume whilst reducing their investment in new infrastructures and beyond that significantly reduce their energy bill. Moreover, the EU political agenda in unison with expected growth in mobile data has identified cost and energy per bit reduction as a stringent design requirement for mobile networks of the future.

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[1] WiFi-D is the new technology in which two devices can communicate with each other in peer-to-peer manner, without the WiFi access point.

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The growth in wireless capacity is exemplified by this observation from Martin Cooper of Arraycomm [2]: "The wireless capacity has doubled every 30 months over the last 104 years". This translates into an approximately million-fold capacity increase since 1957. Breaking down these gains shows a 25× (times) improvement from wider spectrum, a 5× improvement by dividing the spectrum into smaller slices, a 5× improvement by designing better modulation schemes, and a whopping 1600× gain through reduced cell sizes and transmit distance. The enormous gains reaped from smaller cell sizes arise from efficient spatial reuse of spectrum, or alternatively, a higher area spectral efficiency [2,3]. According to the above observation, the smaller the distance, the higher the data transfer rate and the lower the energy consumption and vice versa.

(a) Basically, short range technologies are divided into two groups according to their spectrum usages: license exempt band technologies and license band technologies. Examples of *license exempt band* technologies are: WLAN, WiFi, WiFi-D, Bluetooth, etc. These technologies are designed for short distance between sender and receiver and therefore achieve very high data rates with low energy consumption.

Femtocells are an example of another short range technology which works in license band. It works underlying with cellular band (e.g. UMTS or LTE-A) and uses limited and expensive spectrum more efficiently. Femtocells [4] are small cellular base stations usually installed at indoor locations using broadband connections for backhaul, intended to extend coverage and offload the mobile macronetwork in home and small office environments. Similarly, relays [5] and picocell [6] are also used for similar purposes. Appendix Aprovides a detailed comparison of these technologies in terms of energy consumption.

The shortcomings of the above-mentioned technologies are as follows:

(1) As WLAN, WiFi, and Bluetooth work in license exempt band, there are no guarantees that they work in every place and there is always the possibility of the presence of interfering communication system or other source of interference.
(2) WiFi-D can be used in every public place in the near future as devices become available, but this technology lacks gobal synchronization. (Synchronization can be used in wireless systems, generally to enable energy-efficient operation. For devices to discover each other, they must rendezvous in space and time. Only in a synchronized system the discovery periods can be both frequent and of low duty cycle. Thus, in practice devices operating autonomously without infrastructure support in unlicensed spectrum can synchronize, but only locally [7].)
(3) On the other hand, femto cells, relays and picocells are all infrastructure based network, traffic goes through a centralized controller, such as a Femto Base Station (FBS) even if the source and destination are close to each other and this will consume more energy as traffic goes in two hops to the destination. (4) (SenderUser → FBS/Pico/Relay → ReceiverUsers).
(5) Femrocells and picocells require a separate backhaul connection and act as a separate base station which increases the installation and energy cost for the mobile operators.

(b) The biggest cost challenge facing wireless service providers today is the backhaul network [8,9]. This infrastructure is very expensive to maintain, energy consuming and difficult to scale. The surge of data traffic is pushing many mobile networks to their capacity limit. More antennas are required to accommodate all users and achieve acceptable signal coverage. More operators are seeking innovative solutions to cope with the rising demand of mobile traffic while minimizing operating costs.

In order to solve the issues mentioned above, to enhance the communication capacities and capabilities, decrease energy consumption per bit and to introduce new services, research is performed on many subjects, e.g. antenna design, data compression, modulation techniques, among others.

A very recent and less tackled topic is device to device (D2D) [10,11], direct terminal-to-terminal (DTT or T2T), peer-to-peer (P2P), handset-to-handset, mobile-to-mobile (M2M), Direct-LTE or ad hoc communication underlying cellular networks.

Qualcomm recently stated in the eetimes Magazine [12] that more than a dozen companies are supporting a proposed standard for device-to-device links in Long Term Evolution handsets. They believe Direct LTE will offer capabilities and power efficiency for location-based applications which are not available in today's Wi-Fi Direct and GPS links based technologies. Direct-LTE is based on line-of-sight links at a range of up to 500 m and 20–23 dBm signaling limits. The technique could discover local users more quickly with less processing overhead than Wi-Fi Direct or GPS. Qualcomm said in its internal tests, LTE Direct discovered as many as 7200 terminals in 0.64 s compared to 369 terminals found in using Wi-Fi Direct that took 82–119 s. A wide range of operators, system and chip companies back the idea. They proposed adding Direct LTE to the 3GPP group's LTE Release 12, slated to be available in 2015.

In this paper we use the acronym D2D, which is commonly used in the literature. In D2D communication, devices are communicating with each other without intermediate nodes (infrastructure less). D2D communication uses cellular spectrum (license band) supported by a cellular infrastructure and promises three types of gain: the proximity of user equipments (UE) may allow for extremely high bit rates, low delays and low energy consumption [13,14]. The reuse gain implies that radio resources may be simultaneously used by cellular as well as D2D links, tightening the reuse factor even of a reuse-1 system [13]. Finally, the hop gain refers to using both an uplink and a downlink resource when communicating via the access point in the cellular mode. Moreover, D2D communication may extend the cellular coverage and facilitate new types of wireless peer-to-peer services. So, D2D is a strong candidate to act as an energy saving approach in next generation wireless communication system.