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Published in:
Proceedings of the IEEE

DOI (link to publication from Publisher):
10.1109/JPROC.2012.2189806

Publication date:
2012

Document Version
Accepted author manuscript, peer reviewed version

Link to publication from Aalborg University

Citation for published version (APA):
Pedersen, M. V., & Fitzek, F. (2012). Mobile Clouds: The New Content Distribution Platform. *Proceedings of the IEEE*, *100*(Special Centennial Issue), 1400-1403. https://doi.org/10.1109/JPROC.2012.2189806

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INVITED PAPER

Mobile Clouds: The New Content Distribution Platform

In this paper, the future of digital media content distribution using mobile clouds is introduced and the impact of social networks on sharing content and other limited resources such as spectrum is highlighted.

By Morten V. Pedersen, *Member IEEE*, and Frank H. P. Fitzek, *Senior Member IEEE*

ABSTRACT | This paper discusses the future of content distribution among mobile devices forming the so-called mobile clouds. This paper introduces the current-technology-based problems of the approach, but also highlights its future potential. One core element of this paper is the technical development in this area and the social paradigm that will be used to create cooperation among users. We conclude that the future of mobile clouds will be in novel technologies such as network coding as well as in combination with social networks in order to boost cooperation among users as well as connect people over the shared content.

KEYWORDS | Cooperation; mobile clouds; network coding; social networks

I. INTRODUCTION

With the dramatic evolution of mobile phones come changes to how we use these devices. From simple phone calls in the past, today the mobile phone is the main source of information storing our favorite songs and videos.

But storing the mobile content is not the final goal. Users like to share content. For this purpose, all social networks such as Facebook allow upload of content of any kind. But users want more than just a common storage of their content. They want to enjoy the content together with their friends simultaneously. This is not a new trend. In the very early days of the Walkman there were already two headset jacks. The great success of the TV as a social medium was that we could watch it together and talk about it later on.

With the introduction of the mobile phone, the consumption of content became more asynchronous. One of the reasons is that the content we watch is a downloaded content. Live streaming such as in Internet protocol television (IPTV) is not widely deployed yet. Unfortunately, our mobile phones and our networks are not completely ready yet to support the described usage scenario. Current networks, for example, have difficulties to support multicast or broadcast services for mass events such as rock concerts or sport events, especially if the receivers are spatially correlated. Furthermore, the social interaction over such content cannot be globalized, but is limited to people which are spatially or socially close to each other. Therefore, the trend tends to share the content in a more cooperative way from device to device (D2D).

Without going into detail, sharing is not limited to content but follows a more general concept of sharing resources. Sharable resources are, e.g., spectrum, computational power, apps, onboard sensors, achieved knowledge as well as the aforementioned content [1], [2]. After answering the question on what will be shared in the mobile clouds, the follow-up question is how will the sharing be realized? Here we will highlight two aspects, namely, the technology side and the social side. The technology side looks into the efficient sharing of the content in a mobile cloud, while the social side discusses different forms of cooperation within the mobile cloud from forced cooperation, altruism, and new forms of cooperation.

II. MOBILE CLOUDS: CURRENT PROBLEMS

Since the very early days of mobile communication, cellular and centralized concepts have dominated the

Manuscript received February 17, 2012; accepted February 21, 2012. Date of publication April 4, 2012; date of current version May 10, 2012. This work was supported in part by the Danish Ministry of Science, Technology and Innovation under the CONE project (Grant 09-066549/FTP). This work was also supported by the Danish Council for Independent Research (Sapere Aude program) under Green Mobile Clouds Project 10-081621/FTP.
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Digital Object Identifier: 10.1109/JPROC.2012.2189806

0018-9219/$31.00 ©2012 IEEE

communication world. This old paradigm limits us. We should break with these concepts and start to think about D2D concepts. As the content is not necessarily stored in the overlay network, devices might convey information directly to the neighboring devices without any help of the overlay network. This technical solution maps perfectly with the social need to share with people who are close to us.

The problem is that the mobile platforms are not, or even worse not anymore, ready for this. Such an approach could be realized by the globally accepted WiFi technology. Most mobile phones, whether featured phones or smartphones, are equipped with WiFi already. In order to not be dependent on any overlay network, *ad hoc* WiFi would be the best choice. But as the first WiFi-enabled phones were still able to support *ad hoc* WiFi, some of the newer devices do not allow it anymore. More precisely, the devices are allowed to join an *ad hoc* network but cannot establish such a network. Even if the *ad hoc* capabilities are supported as, for example, on some Android phones or the Nokia N9, the performance of *ad hoc* communication was reported to be rather low. Fortunately, WiFi direct is now implemented on the newest phones. This will boost the D2D communication platform. Whatever technology is available, network coding has to be implemented for the efficient exchange of the content. In case the content is not stored on any participating mobile, but within the Internet, D2D still offers many benefits. Without the D2D capability of mobile devices in close proximity, the network operator needs to make sure that each participating mobile phone gets full information. In case of D2D, the network would just pump enough information into the D2D group and leave it up to the phones to exchange the missing parts. Such an approach leads to not only energy saving for the mobile phones, but also energy and bandwidth savings for the network operators.

Another problem has to do with legal aspects: Which content can be used for D2D networks? Downloadable content is most often digital right management (DRM) protected. This last problem may be solved by identifying users that would like to share the same content and setting up an efficient transmission among them.

III. MOBILE CLOUDS: THE FUTURE

Here we highlight the future of the mobile clouds with respect to content distribution. We will examine two main aspects, namely, the technological and social domains.

A. Technological Domain

Currently, there is a lot of research work going on to make the communication within the mobile clouds feasible and highly attractive for users, network operators, and service providers. A key element here is the network coding. Introduced by Ahlswede *et al.* [3], the main contribution was done later by Ho *et al.*, who introduced the random linear network coding [4]. Using network coding for the distribution of content within a mobile cloud leads to energy savings, bandwidth savings, delay reduction, privacy assurance, as well as preventing false packet injection. It has been shown that the implementation of network coding on any mobile platform is feasible and the energy spent for operating network coding is less than the energy savings that will be achieved by the reduced bandwidth requirements. First applications for mobile phones have been prototyped [5], showing the benefits of network coding. Conceivably mobile clouds will be powered in the future by network coding due to the list of benefits given beforehand. Fig. 1 shows one of the first content sharing demonstrations [5]. One sender shares a video with 16 receivers in close proximity.

B. Social Domain

A more interesting question is how can cooperation among mobile phones be achieved? It is critical to understand the reasoning behind users' cooperation or defection in order to influence users' willingness to participate. In Fig. 2, four different modes of cooperation are shown: forced cooperation, technology-enabled cooperation, socially enabled cooperation, and altruism. Forced cooperation takes place if, for example, the content is shared to any requesting device without asking the content holder whether she or he agrees. As this may be seen as disadvantageous for the content holder, it has huge benefits for the network operator. If mobile devices have different owners, cooperation becomes more difficult. In its easiest form, cooperation takes place if it is based on altruism. Here, the content holder is willing to share content with friends and family and even strangers. As shown by Hamilton in 1963 [6], in human science, some mobile devices willingly sacrifice some of their own

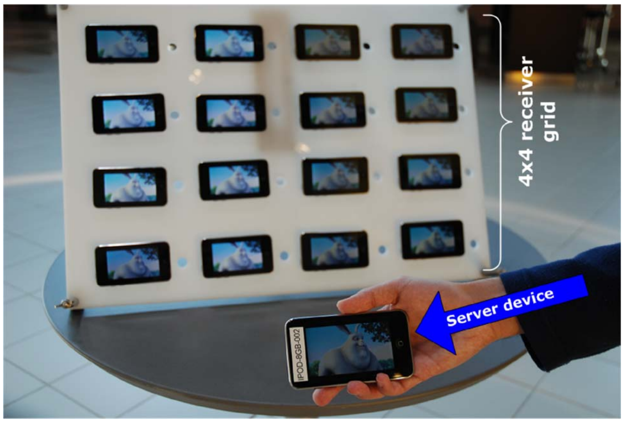

Fig. 1. ***Example of sharing a movie locally among mobile devices using WiFi technology for the iOS platform.***

Forced Cooperation	Technology enabled	Socially enabled	Altruism
B and C does not matter	B>C	B'>C	Hamilton Rule B*r>C
There is no understanding of costs and benefits	Users see the instantaneous gain in cooperation	Users do not gain by cooperation as such but show off in their social cycles	Users do not care too much about their own gain but happy to help

B: benefit C:cost

Fig. 2. ***Different cooperation modes.***

benefits in favor of others, as long as $B^*r > C$, where B is the expected benefit for the receiver of the donation, C is the cost involved for the donor, and r is the relationship between the two entities.

The easiest way to encourage the use of cooperative technologies is to create situations where the instant benefit (B) is larger than the cost (C) of undertaking cooperation for all participating users. The better we design the technology the lower the costs are. Cooperative IPTV, as introduced in [7], where users cooperate during downloading of the prefetched TV content, undoubtedly exemplifies this point. In order to find more scenarios, new communication protocols and techniques are needed. Should the benefit of cooperation remain unclear to all users, social reinforcement will kick in. In such a scenario, we predict one or more mobile devices gaining from the cooperation (we call them the *receivers*) and one or more entities who invest in cooperation but do not gain (we call them the *investors*). While the gain for the *receivers* is clear, the gain for the *investors* is not. It is well documented that most users of mobile devices are members of social networks such as Facebook and Google+. When *investors* help establish cooperation with little to no perceived benefit to them, their efforts should be rewarded in social networks with a different kind of benefit (B) (see Fig. 3). This can be done by simple notification or other gamification concepts. The gain for the *investors* is therefore within the social domain where they will obtain rewards from the *receivers* as well as their own social graph. While forced cooperation and altruism are two well-known concepts that represent the state of the art, technology and socially enabled mobile clouds are undoubtedly beyond the state of the art. In contrast to any other tit-for-tat cooperation scheme such as FON [8] or BitTorrent [9], the cooperative exchange is not repaid with equal currency but is rewarded within a new dimension: the social domain.

Currently, social networks dominate the information and communication technology (ICT) world and will become even more pervasive in the future. Social networks will not only boost cooperation among mobile devices, but also they will allow social commentary about the content currently or recently shared. Such an approach has several advantages for the:

- *User*: content sharing is faster and more energy efficient compared to cellular download; simultaneous consuming of digital content (music, video, pictures);
- *network operator*: local sharing will offload the overlay networks where spectrum is a scarce resource;
- *service/content provider*: content will be spread quickly and viral loops will be established, spreading interesting content with larger speed.

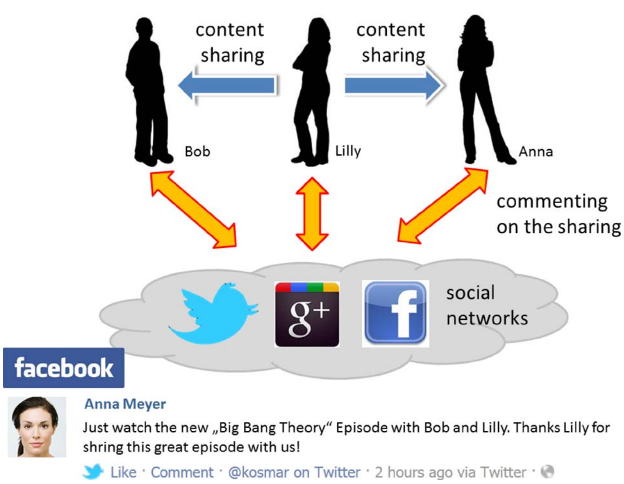

Fig. 3. ***Local sharing with social networks to enable cooperation and discuss the digital content.***

IV. CONCLUSION

In this paper, the future of content distribution for digital media using mobile clouds is introduced. The mobile cloud concept foresees that mobile devices connect to each other directly without any help of the overlay network. For the actual sharing among mobile devices new technologies such as network coding are the key enabler for support of energy saving, privacy, security, data protection, and fast exchange of data. This new architecture fits the needs of users who would like to enjoy the digital content together. In order to boost cooperation, especially for users who do not know one another, the social networks are introduced. By means of social networks, mismatch in cooperation gain can be balanced out.

In this paper, we only highlighted the impact of social networks on content sharing only, but in the future, users might also share other resources such as spectrum, onboard sensor information with each other, using the reporting capabilities of the social networks. ■

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Dr. Fitzek received the 2005 YRP award for the work on MIMO MDC and the Young Elite Researcher Award of Denmark. He received the Nokia Champion Award several times in a row from 2007 to 2011. In 2008, he was awarded the Nokia Achievement Award for his work on cooperative networks. In 2011, he received the SAPERE AUDE research grant from the Danish Government.