C2POWER Approach for Power Saving in Multi-standard Wireless Devices

Ayman Radwan[1], Jonathan Rodriguez[1], Álvaro Gomes[2], and Eduardo Sá[2]

[1] Instituto de Telecomunicações, Aveiro, 3810-193, Portugal
{aradwan,jonathan}@av.it.pt
[2] Portugal Telecom Inovacao SA, Rue Jose Ferreira Pinto Basto, Aveiro, 3810-106, Portugal
AGomes@ptinovacao.pt, eduardo-l-sa@ext.ptinovacao.pt

Abstract. 4G networks promise higher data rates and continuous connectivity to multi-standard mobile devices, but at the expense of higher power requirements. Energy is a critical resource for mobile devices, which depend on batteries for power supply. Battery capacity is finite and battery industry is slow, with no promises of any breakthrough in the near future. Therefore, there is a critical necessity for developing new disruptive energy saving techniques, if mobile users are to enjoy the offered advanced applications while roaming freely, in addition to having more environmentally friendly systems. Otherwise mobiles users will relentlessly be searching for power outlets rather than network access, becoming once again bound to a single location. To avoid the so called 4G "Energy Trap", the ICT-C2POWER project addresses the issue of power efficient communication from the user devices through to the core infrastructure of the network and investigates how different entities interact with each other. The C2POWER project will investigate how cognitive and cooperative techniques can be applied for reducing power consumption of wireless mobile devices. The goal of C2POWER is to study, develop and demonstrate energy saving technologies for multi-standard wireless mobile devices, exploiting the combination of cognitive and cooperative techniques. This paper provides an overview of C2POWER project, highlighting its innovative approach, the considered scenarios, and challenges.

Keywords: Energy Saving, Cognitive Radio, Cooperative Communication, Energy-aware radio, Vertical Handover, Energy Trap.

1 Introduction

Green communication paradigm shift for designing power efficient communication systems is currently a main direction for most manufacturers and operators, not only to decrease pollution but also to save costs by optimizing the power usage in wireless communication systems. There is a definite necessity for new approaches for power saving in wireless mobile systems, in order to allow mobile devices to utilize the advanced applications offered in present and future networks.

4G systems are expected to provide a true mobile experience to mobile users, with higher data rates and better QoS (Quality of Service). True mobile experience means

J. Rodriguez, R. Tafazolli, C. Verikoukis (Eds.): MOBIMEDIA 2010, LNICST 77, pp. 440–451, 2012.

the freedom to roam around freely, while always being connected to some type of network. In fulfilling these goals, 4G systems consist of overlapping heterogeneous networks, requiring multi-standard wireless mobile devices. Multi-standard mobile devices have higher ability to stay connected, but also higher power requirements.

Mobile devices depend on rechargeable batteries for their power supply. Battery capacity is finite and the progress in battery technology is slow. Battery capacity has increased by only 80% within the last decade [1], compared to processing performance, which doubles every 18 months following Moore's law. No breakthrough is expected in battery industry unless completely new technologies are invented.

With the increase in data rates and the multi-standard interfaces, the power requirements of mobile devices are increasing. Additionally, other advanced capabilities (for example GPS and advanced imaging features like camera, high-definition displays, etc…) are deployed on mobile devices. These advanced features increase the power requirements of mobile devices even more, which will make active cooling a necessity in mobile devices. Active cooling is not an attractive solution for users and manufacturers, despite some active researches that started studying the performance of fans within mobile phones [2].

It is clear that there is a growing gap between energy requirements of emerging wireless mobile devices and what can be achieved by the progress in battery technology, circuit design, and thermal and cooling techniques. Hence, one of the biggest impediments of future wireless communications systems is the need to limit the energy consumption of the battery-driven devices so as to prolong the operational times and to avoid active cooling. In fact, without new approaches for energy saving, there is a significant threat that the 4G mobile users will be searching for power outlets rather than network access, and becoming once again bound to a single location, a phenomena which is sometimes referred to as "energy trap" of 4G system [3]. Even if new technologies could achieve the energy and thermal requirements of future mobile devices, environmental and human exposure to radiation issues will continue to exist requiring solutions to decrease energy consumption.

There is a definite need for new disruptive strategies to address all aspects of power efficiency from the user devices through to the core infrastructure of the network and how these devices and equipment interact with each other in an energy-efficient manner. ICT-C2POWER (Cognitive radio and Cooperative strategies for POWER saving in multi-standard wireless devices) project is the vehicle to address these issues through cognition and cooperation.

Cognitive radio and cooperative networks are becoming key disruptive technologies in the field of wireless communications. Cognitive radios have always been used to improve spectrum efficiency and cooperative strategies are mainly developed for enhancing wireless link capacity. C2POWER project will go beyond the state-of-the-art by investigating how cognition and cooperation can be applied for reducing power consumption of wireless mobile devices.

Although C2POWER main concern is power efficiency on the mobile terminal side, the anticipated results are expected to decrease the total energy consumption of all entities of the network or at least give indicative directions for solutions to reduce power consumption on the network side as well.

This paper presents the main approach of C2POWER project. The rest of the paper is organized as follows. Section 2 presents the objectives of C2POWER. The scenarios considered in C2POWER are presented in Section 3, highlighting the challenges of the project. Section 4 describes the basic approach, main functionalities and innovations of C2POWER. There is a need for business model for cooperation, which is discussed in Section 5. Section 6 concludes the paper.

2 Objective

4G Heterogeneous wireless networks and the battery powered multi-standard handset devices connected to them introduce new complexities which define new requirements in terms of power efficiency to guarantee battery life-time, environmental and thermal criteria. In this context, C2POWER main objective is to research, develop and demonstrate energy saving technologies for multi-standard wireless mobile devices, exploiting the combination of cognitive radio and cooperative strategies, while maintaining the QoS requested based on the type of active applications.

Up till now, cognitive radios and cooperative strategies have been mainly used for achieving better spectrum utilization and higher system capacity. For the first time, C2POWER project will investigate how cognition and cooperation can be extended to allow the system not only to manage shared spectrum, but to use context information ("knowledge") to decrease the overall energy consumption and radiated power of mobile devices, while maintaining the required performance in terms of data rate and QoS.

The focus of the project includes two main components; The dominant component deals with technical aspects, while the second addresses business/management models related to the topic of the project and techniques under study.

At the technical level, the main goals are primarily:

- Use context aware information by cooperative strategies to achieve power efficiency at the mobile terminal side and extend mobile devices' battery lifetime.
- Investigate the potential of cooperative techniques based on advanced short range communications for power saving of mobile wireless devices.
- Investigate energy-efficient vertical handover procedures and policies between heterogeneous technologies with the main motivation being power saving.
- Design energy efficient reconfigurable multi-standard transceivers (BB and RF) able to switch from one standard to another according to power saving strategies.

At the management/ business models, the main goal is to:

- Investigate methods and incentives to encourage cooperation among users/handsets and develop attractive business models for the network/service providers to stimulate and motivate cooperation among users and heterogeneous networks.

As a consequence, the project will help emerging standardization groups to move from the classical non cooperative paradigm, where mobile devices and heterogeneous networks are considered as individual entities towards a cooperative approach, where cognitive devices are able to cooperate while treating all entities as a pool of opportunities to save battery power of mobile devices. C2POWER will provide sufficient evidence on the technology and economic viability and its deployment.

3 Reference Scenarios and Use-Cases

C2POWER project defines three reference scenarios, which are considered in the context of the project. The three scenarios determine the different levels of combination between cooperation and cognition. For a good understanding of the technical approach of the project, the three scenarios are presented, in addition to use-cases, to elaborate on the importance of C2POWER.

3.1 Scenario 1: Short-Range Cooperation in Homogenous Network

This scenario considers the presence of one infrastructure-based RAT (Radio Access Technology), which can be UMTS, LTE, WiFi or WiMAX. In addition to the infrastructure air interface, mobile devices are equipped with a short-range cooperative air interface, which is based on low power technology, like UWB, Bluetooth, etc. mobile devices located in the vicinity of each other form a cooperative cluster, which is mainly motivated by power saving. Some mobile devices may need some incentives to join the cluster. These incentives are discussed at the end of this paper. Using the spatial proximity and diversity within a group of cooperative mobiles, there is a high potential for power saving through cooperative short-range retransmission. The details of the scenario can be seen in Fig. 1. In the figure, node A is connected to the RAT but is running low on battery. Based on cognitive information, node A is aware of the presence of a short-range cluster in its vicinity and decides to use cooperative short-range communication to connect to the same RAT. Node A uses cooperative short-range communication with node B and/or node C to reach the same centralized RAT.

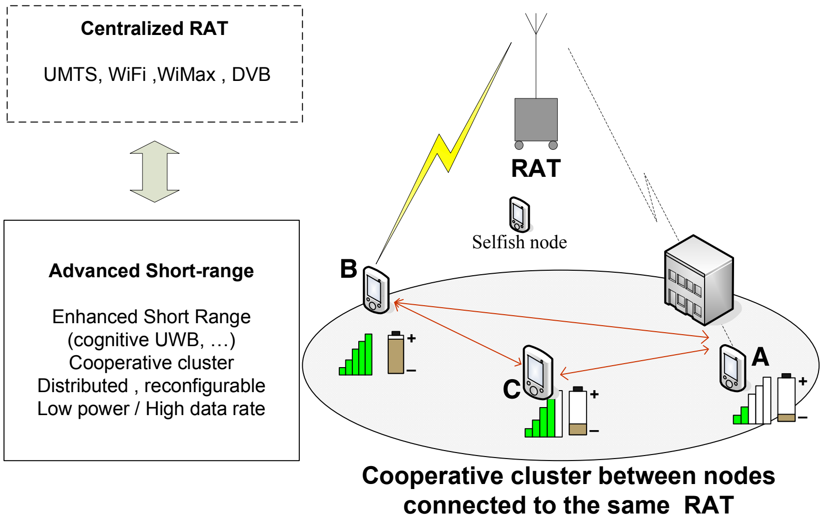

Fig. 1. Short-range cooperation between nodes using the same RAT

Use-Case: Environment Conference

Ana is about to start her presentation at the Environmental Conference in Copenhagen. Before the beginning of her talk, she uploaded her presentation and useful resources about "Energy Consumption in Hi-Tech"; which are made available for the audience on an FTP server to download. This allows participants to follow the presentation and take notes. Before the talk, the attendees were informed about the resources on the FTP server.

Most of the participants downloaded the slides and were following the talk, while checking their email, browsing the web for information about the contents of the presentation, using their laptops, smartphones, ipads, etc.

Ana knows that the presentation is a bit long and that most participants use multi-standard wireless devices with high power requirements. She is worried that user devices will run out of battery before the end of the presentation.

The organizers of the conference are not worried because they have installed equipments that implement C2POWER energy saving policies, which can discover cooperation opportunities for power saving. Using context information, C2POWER agent chooses devices with better connection to Wi-Fi access as relaying nodes for devices with worse channel conditions. This way power saving is achieved, especially for devices with bad channel conditions. C2POWER is intelligent enough, so that it switches the role of relaying nodes between different devices to avoid depleting the battery of one device too quickly.

3.2 Scenario 2: Energy-Efficient Handover Exploiting Heterogeneous RATs

4G systems are expected to provide continuous connections, or as it is typically referred to "always being connected". 4G mobile devices are equipped with multiple interfaces to stay always connected. The existence of multiple heterogeneous RATs is also required. This scenario considers that several RATs are available in the location of a multi-standard mobile device. Using cognition and intelligent network discovery mechanisms, C2POWER will enable mobile devices to find the most suitable interface for power saving. Energy-efficient handover policies will be advised to provide mobile users with the best service experience conserving the optimal QoS in addition to saving energy.

Multi-standard mobile devices have high power requirements for maintaining multiple radio interfaces. C2POWER will investigate strategies based on context aware information to allow mobile devices to switch OFF interfaces while not in use, and only switch ON a certain interface when there is a possibility of a handover to that interface. The algorithms will make use of the available information on the network side, like the 3GPP ANDSF (Access Network Discovery and Selection Function) [4] or the IEEE 802.21 MIIS (Media-Independent Information Service) [5]. Fig. 2 shows scenario 2, where a multi-standard mobile device is connected to RAT1, which is consuming high power. Using C2POWER intelligence, the multi-standard mobile device was able to discover RAT2, which is more energy efficient for the mobile device based on its location, type of application, in addition to other context information. The mobile device switches ON the specific interface and performs handover to RAT2.

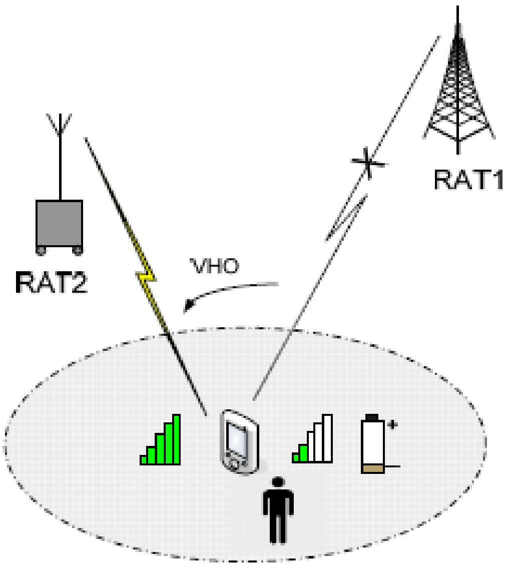

Fig. 2. Energy-efficient handover between heterogeneous RATs

Use-Case: City Tour

Uwe has just arrived to the São Bento Train Station, in Porto. He calls his girlfriend, informing her of his safe arrival. He is here for a conference, which is scheduled for the next day.

Uwe decides to do a day tour in the city. He is very impressed with the architecture of the city, which is very different from the old German style of his city, Dresden. He starts taking pictures with his smartphone.

After some hours, he decides to take a break and relax at one of the *cafés*. While resting, he uploads some pictures to his Picasa account to share with his girlfriend.

At the end of the day, he realizes that the battery of his smartphone has lasted more than it usually does. He is not aware that the city is using C2POWER architecture and procedures to optimize the energy consumption of his multi-standard phone.

Once Uwe arrived in Porto, the mobile network has been monitoring his mobile phone conditions gathering context information and execute network control procedures.

The Porto Mobile Network is interconnected with a mobility manager that allows for inter-network mobility. The mobile phone is always connected to the most energy efficient interface. For each specific service, C2POWER analyzes the network and the mobile phone status, and connects the mobile phone to the best access network. For example, when Uwe was talking to his girlfriend, he was using the 2G network, since it was the RAT that required the least energy inside the train station while supplying the required QoS, but while uploading the photos, the mobile phone was connected to the nearby Wi-Fi hotspots.

3.3 Scenario 3: Short-Range Cooperation among Heterogeneous RATs

The last considered scenario envisages an efficient use of heterogeneous RATs, which are considered globally as a pool of opportunities rather than as independent entities. The scenario is a merger of the energy saving features from both Scenario 1 and Scenario 2. Mobile devices exploit all energy saving possibilities, including short-range cooperation and energy efficient vertical handover between different RATs. Fig. 3 describes Scenario 3, where Node B is initially connected to RAT 2. Using context-awareness capabilities, Node B detects the presence of a node in its vicinity, which is ready to cooperate using short range communication (e.g. UWB). After the negotiation between both nodes, it is determined that Node A can provide the required QoS of Node B, through relaying to RAT1. In addition, this short-range cooperation has lower power requirements, resulting in increasing the battery life time of Node B.

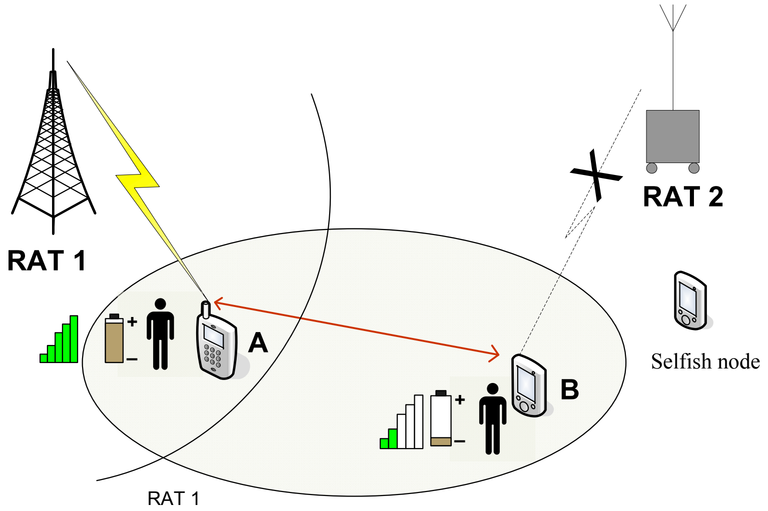

Fig. 3. Short-range cooperation among nodes using heterogeneous RATs

Use-Case: City Tour (Extended)

The use case of Scenario 3 is simply the combination of the use-cases of both Scenarios 1 and 2. In the city tour example, Uwe performs energy-efficient handovers to stay connected to the most energy-efficient RAT. In addition, during his tour, Uwe may step inside a shopping mall to buy some gifts for his friends. Inside shopping malls, there are many opportunities for forming short-range cooperative clusters, sometimes even using nodes which are wired or are being charged (i.e. No problem with power supply). Using context information and based on Uwe's slow speed inside the mall, the network detects the opportunity for switching Uwe's mobile phone connection from 3G network to short-range cooperative relaying to one of the Wi-Fi access points of the shopping mall. The battery of Uwe's mobile phone lasts longer than it ever did before thanks to the intelligence of the C2POWER based networks.

4 C2POWER Approach

The objectives within C2POWER will be implemented according to the defined scenarios and the end goal will be to design, develop and evaluate the algorithms that will enable reducing energy requirements based on short-range cooperation and cognitive protocols/algorithms.

The key concept of C2POWER relies on the ability of the mobile devices to use multi-standard air interfaces, which enable mobile devices to use intelligent handovers between heterogeneous RATs, as well as to establish cooperation with nearby devices using low-power short-range communication, to achieve the least energy consumption. C2POWER main scheme resides in the intersection of cooperation, heterogeneous networks, and advanced short-range communications, while exploiting context aware information about the surrounding environment using cognitive radios, as shown in Fig. 4.

C2POWER innovation is using cognitive and cooperation strategies, which have mainly been used for enhancing spectrum efficiency and wireless link capacity, for power saving in the mobile devices.

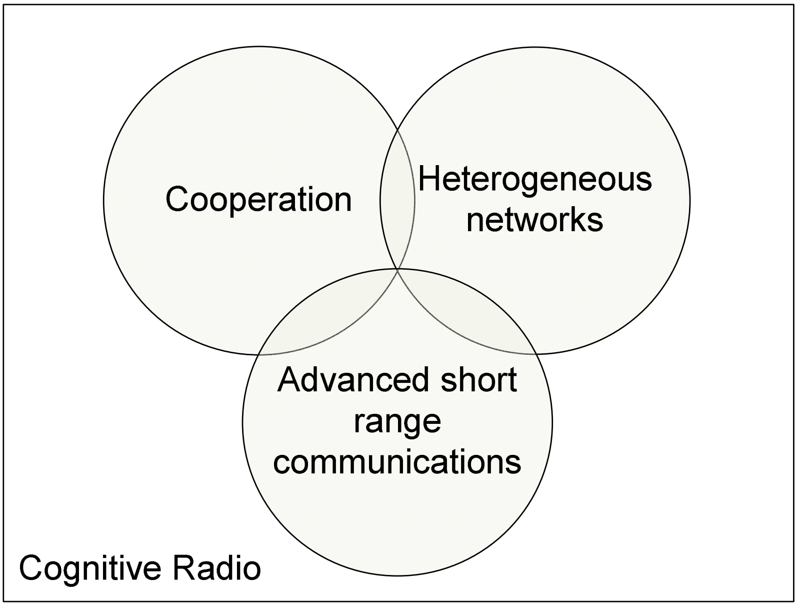

Fig. 4. Key Research tracks of C2POWER

The architecture and algorithm design will progress along a number of collaborative tracks, with milestones including the implementation of the hardware components and modules to demonstrate two major showcases, namely short range cooperation for power saving and energy-efficient cognitive handover procedures. The main tracks include:

Context Awareness and Signaling

Using cognitive radios, context aware information is extracted. Information about available RATs and nodes in the vicinity of mobile nodes is extracted using cognition and cooperative sensing and is used by mobile devices in the process of network/node discovery. Additionally, C2POWER concept will make use of available information in entities like ANDSF in 3GPP [4] and MIIS in IEEE 802.21[5]. Useful parameters like frequency bands used by available networks and short range collaborative clusters are also extracted to save energy needed for scanning different frequency bands. Context aware information, like battery level and speed of nodes and capabilities of RATs, will be used to determine the most energy efficient connection option. Under this umbrella, node and network discovery mechanism will be studied and tested to determine the most energy efficient mechanism to use.

C2POWER will also use history of context aware parameter, to predict the user (mobile device) future behavior, which can help in saving energy in various ways. For example, monitoring user mobility, C2POWER mechanism can predict which RATs coverage the mobile device will reside in and for how long. Based on these context information, C2POWER mechanism can instruct the mobile device to switch ON or OFF certain radio interfaces to save energy in addition to which frequency bands to scan instead of scanning a wide range of frequencies.

Cooperative Short-Range Communication for Power Saving

Cooperative short-range communication procedures for power saving will be defined. Utility functions will be defined to help in determining the best nodes to cooperate with. In addition, energy efficient routing and cooperative relaying will be studied to achieve the most energy efficient communication, using context aware information such as battery levels and mobility profiles of nodes. Such parameters are useful in determining useful nodes that should be used for cooperation. For example, nodes with low battery level or high mobility are avoided in routing algorithms.

Energy-Efficient Cognitive Handover Procedures

Energy efficient handover procedures will be defined. Handover procedures will make use of available context aware information to save energy when switching between heterogeneous RATs.

Energy-Efficient Reconfigurable Radio Transceivers

All previous techniques will be designed on top of energy efficient multi-standard transceivers, which will be defined within the scope of the project. C2POWER mobile devices will have multiple radio interfaces, which will use innovative techniques for switching between different interfaces including short-range communication.

Different tracks studied in C2POWER project and the interaction between them are shown in Fig. 5.

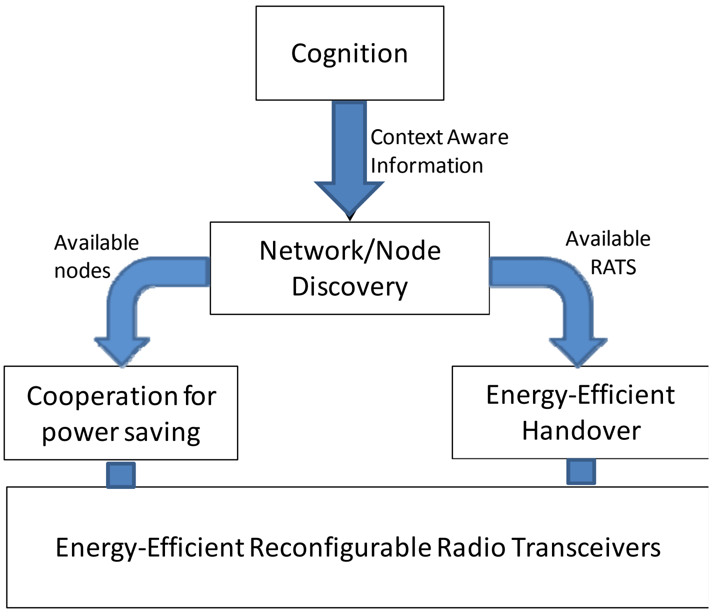

Fig. 5. C2POWER Approach

5 Business Model and Incentives

In addition to the technological impact, C2POWER will also open up new business opportunities for providers. One of the pivotal technologies in C2POWER is exploiting cooperation for power saving. Using cooperation, some devices have to sacrifice resources - being battery power, bandwidth, etc- to assist nearby devices. Incentives are needed to motivate users to allow their mobile devices to assist other devices, which belong to different users. Cooperation hence promotes attractive business models for network/service providers to compensate/pay off cooperating nodes (users) which assist other nodes. A centralized payment system to promote non-altruistic cooperation can be used, as shown in Fig. 6. Additionally, reputation systems need to be studied in the course of the project. Reputation systems provide ways to distinguish cooperative nodes from selfish ones, to enable an informed decision about which nodes to cooperate with and which nodes to avoid. Finally C2POWER mechanisms have to consider fairness among nodes, to avoid the collapse of cooperation and the well known “tragedy of the commons” phenomenon.

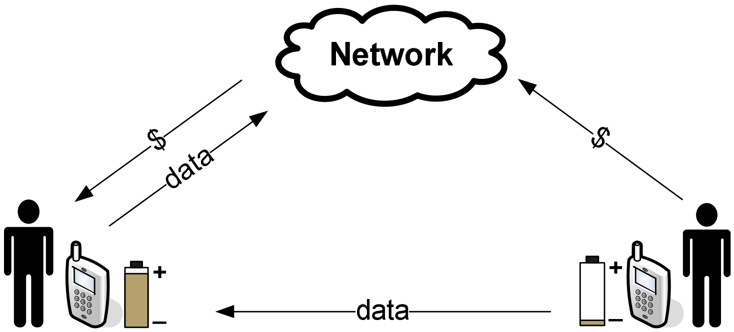

Fig. 6. Incentives and business model to motivate nodes to cooperate sacrificing battery power, bandwidth, etc.

6 Conclusion

With the advanced service offered by 4G and future networks, increased energy requirements are expected. Mobile devices depend on batteries for their power supply. Battery capacity is finite and a breakthrough in the battery industry is not expected in the near future. Without any new disruptive approaches for energy saving, 4G mobile users will relentlessly be searching for power outlets rather than network access, and becoming once again bound to a single location. To avoid the 4G "Energy Trap" and help decrease wireless mobile devices contribution to CO2 emissions, there is a definite need for new approaches to address ways of power saving for communications from mobile devices to the core infrastructure of networks. In this context, the ICT-C2POWER project is exploiting new approaches, by targeting cognitive radios and cooperation strategies, to devise energy-efficient mechanisms for wireless communications of mobile devices.

Acknowledgments. The research leading to these results has received funding from the European Community's Seventh Framework [FP7/2007-2013] under grant agreement number 248577 [C2POWER].

References

1. Anderson, C., Freeman, D., James, I., Johnston, A., Ljung, S.: Mobile Media and Applications, From Concept to Cash: Successful Service Creation and Launch. Wiley (2006)
2. Walsh, E., Grimes, R., Walsh, P.: The Performance of Active Cooling in a Mobile Phone. In: Thermal and Thermo Mechanical Phenomena in Electronic Systems, ITHERM Conference (2008)

3. Fitzek, F., Katz, M.: Cognitive Wireless Networks: Concepts, Methodologies and Visions Inspiring the Age of Enlightenment of Wireless Communications. Springer (2006)
4. TSI TS 123 402 V9.3.0, Universal Mobile Telecommunications System (UMTS); LTE; Architecture enhancements for non-3GPP accesses
5. EEE P802.21/D10.00, Draft Standard for Local and Metropolitan Area Networks: Media Independent Handover Services. IEEE (April 2008)