COMMUNICATE GREEN
Energy Efficient Mobile Communication

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Abstract: In order to fulfill today's high demands on mobile network usage, mobile network providers in Germany have around 100.000 base stations working 24/7. The permanent availability of those network components causes a significant energy consumption. Through an adaptive and context-aware power management in mobile networks, a considerable amount of energy can be saved by maintaining the high quality of experience at the same time. There are a lot of contextual information present in mobile network components and end devices, which can help to calculate decisions for a dynamic de- and reactivation of network components. This position paper discusses the idea of a context entity that aggregates and processes various types of contextual information, and the integration of it into the mobile network architecture.

1 INTRODUCTION

Modern and future radio networks, such as WiFi, UMTS or LTE, provide good connectivity and high data transfer rates to the mobile user. In order to fulfill these requirements, mobile network providers in Germany have around 100.000 base stations working 24/7 with a total power consumption of 760 GWh to 3040 GWh per year. However, these capacities are not always fully utilized, e.g., in rural areas or at night. Furthermore, mobile services that are mostly in use today (e.g., telephony, SMS, etc.), do not have high data rate requirements. Even though the demand on bandwidth for mobile Internet increases continuously, a lot of the services used today can be implemented with older networks (e.g. GSM or EDGE) without any noticeable loss in quality. These examples show that there are massive potentials to save energy in radio access and core networks. This can be done by dynamically de- and reactivating network components (e.g., base stations) or by adaptively reconfiguring the network to the user's needs based on a certain information basis gained from the network.

The main objective of the project *Communicate Green* is the development of an adaptive, context-aware and technology-comprehensive power management for modern radio networks, with which a considerable amount of energy can be saved by maintaining the high quality of experience at the same time. There are a lot of contextual information present in mobile network components and end devices, which can be useful in order to calculate decisions for a dynamic de- and reactivation of network components, such as the current load of a cell, the average daily load of a cell, the number of users in a cell, service usage profiles or QoS requirements. This paper mainly discusses the idea of developing a context entity that aggregates and processes various types of contextual information coming from mobile network components as well as end devices, and the integration of this entity into the mobile network architecture.

2 OBJECTIVES

The project *Communicate Green* is about implementing an adaptive and context-aware power management in radio networks having a global view on different overlay networks. To achieve a high power efficiency throughout different mobile network technologies, all parts of the system are going to be optimized.

Radio network infrastructures are most of the time fully active even when they are not fully utilized (see

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Figure 1). Only in some regions, where the utilization is foreseen, base stations are temporarily switched off. The parameters are not very sophisticated and dynamic, such as the time of the day or special knowledge about certain activities in the region. A simple optimization can be achieved by adjusting the parameters of a mobile network to the actual operating state and by providing only the needed capacity. Possible approaches are the dynamic de- and reactivation of base stations and the transfer of coverage to neighboring base stations.

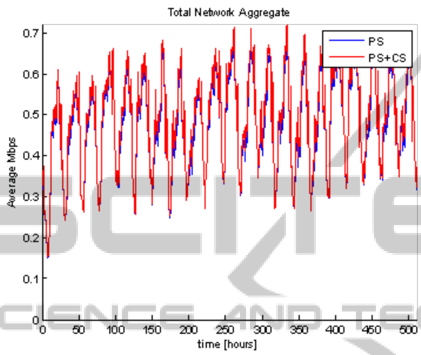

Figure 1: Daily load profile of a telecommunication network in January 2009, Ericsson GmbH.

The potential of optimizing mobile networks in terms of energy efficiency can be increased by creating integrated power management concepts for heterogeneous radio networks. One possible approach is the adaptive configuration and selection of radio networks based on decreasing the power consumption by maintaining a high quality of experience for the user. Figure 2 shows an exemplary night mode, in which 3G/4G cells and WiFi HotSpots are configured in a way that only one base station is active in order to guarantee basic services and a few WiFi HotSpots that deliver broadband data rates.

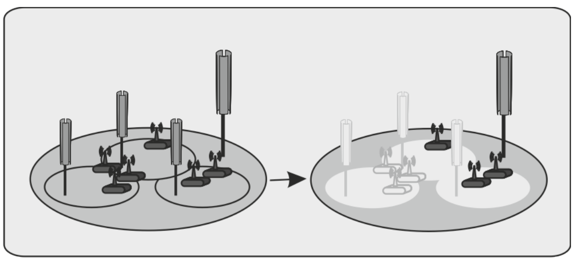

Figure 2: Exemplary deactivation of network nodes.

Changes in radio access networks as they are mentioned above directly affect the core network. In order to assure that all functions in the core network can be delivered without any loss in the quality of service, the core network has to be optimized as well. Virtualization of functions is the key approach here.

The basis for these network optimizations is built by various types of information present in mobile network components, end devices and other sources – here named as context. A list of relevant contextual information will be determined by examining different mobile network context sources. Furthermore, a service classification scheme will be developed showing what kind of service can be delivered by what kind of radio technology. The main focus of our work in the project is the development of a context entity that aggregates and processes contextual information in order to calculate decisions for network optimizations. By applying various context acquisition approaches, both the network as well as the user view will be included into the power management process.

3 RELATED WORK

The problem of energy consumption is also recognized by other project groups. The *EARTH* project (EARTH, 2010), for example, funded by the EU, investigates the energy efficiency of mobile communication systems in order to develop a new generation of energy efficient equipment, components, deployment strategies and energy aware network management solutions. It mainly focuses on LTE, its evolution LTE-A and beyond. *Communicate Green*, however, considers all available radio technologies (e.g., GSM, UMTS or WiFi) and applies energy efficient decision algorithms on available hardware and networks based on network, service and user context.

Therefore, a context entity containing context quality, provisioning, modeling and reasoning mechanisms plays a big role in this project. A lot of research has been done in this field so far. (Floréen et al., 2005) describe a context management framework developed within the *MobiLife* project (MobiLife, 2006), which handles context information, modeling and reasoning for mobile applications and services. For this purpose, essential functionalities are split into different components, which can be configured for different tasks and reasoning methods. (Mannweiler et al., 2009) uses the concept of a context management architecture in order to apply context information for intelligent radio network access (IRNA) purposes. As presented by (Schneider et al., 2010), this architecture is also able to integrate any kind of context provider (e.g., sensor or mobile devices) in a "plug-and-play" manner irrespective of type, manufacturer or accuracy in order to collect context information useful for the mobile communication industry and network operators.

A good overview about context modeling approaches and reasoning techniques is given by (Bettinia et al., 2010). The authors come to the conclusion that hybrid context modeling approaches are a promising direction discussing also a possible hybrid architecture.

4 ARCHITECTURE

The architecture comprises two parts: the functional and the system architecture.

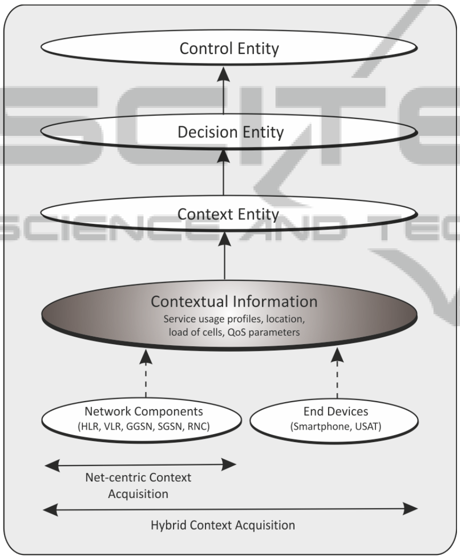

Figure 3: Functional Architecture.

The functional architecture (as illustrated in Figure 3) encapsulates the functions of the system to logical entities and illustrates the relations between them. An integral part of the functional architecture is the data – here named as context information – with which decisions for a dynamic de- and reactivation of network components are calculated. Based on the context model and service classification scheme mentioned above, various types of contextual information can be considered.

The context entity collects and aggregates contextual information by applying two different approaches. In the net-centric context acquisition approach, data is only extracted from network components. This approach has the advantage that already available data (e.g., coarse location data delivered by the HLR, VLR or RNC) can easily be integrated into the context aggregation process. However, the user's view is completely ignored in this approach, so that deactivations calculated by the system might lead to a bad quality of experience for the user. In order to reduce this problem, context is also acquired using the hybrid approach that considers context data from end devices as well.

The decision entity uses the collected contextual data in order to make a decision concerning de- or reactivation of components, whereas the control entity controls and manages de- and reactivations.

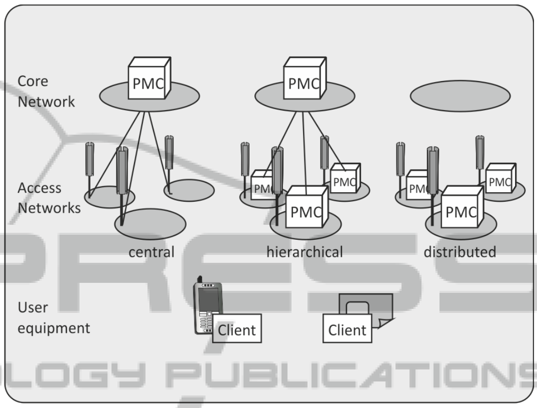

Figure 4: System Architecture.

In the system architecture (see Figure 4), the functional entities are mapped to system components. Data is directly extracted from network components and from end devices via dedicated client applications on modern smartphones. However, due to the mass of different and diverse mobile end devices subscribed to the mobile network, it is quite impossible to consider all mobile users and operating systems. The UMTS SIM Application Toolkit provides potentials to avoid this problem since it allows the implementation of value-added services on the SIM card that can acquire different information from the network regardless of the mobile phone in use. Because of this, context data acquisiton possibilities via the USAT will be analyzed and implemented as well.

The context, decision and control entity are merged to one component called the *Power Management Component (PMC)*. Various options to integrate this component into the topological structure of the network are going to be examined. In a *central* architecture, for example, each mobile network provider has a PMC in his core network controlling and managing the whole infrastructure of the network. Using a *hierarchical* approach, on the other hand, would lead to many PMC nodes in the access networks controlled by a central PMC in the core network. In a *distributed* implementation, the PMC nodes are only in the access networks organizing themselves when de- and reactivating network components.

5 EXPECTED RESULTS

The power consumption of base stations differs from manufacturer to manufacturer. Typical values are between 750W and 3000W[1] per base station.

Table 1: Number of base stations in Germany.

Provider	GSM	UMTS	Total
Deutsche Telekom	25000	11000	36000
Vodafone	20000	13000	33000
O2	17000	10000	27000
E-Plus	18804	6616	25420
	80804	**40616**	**121420**

Taking the base station numbers (O2, 2010) (KPN, 2009) (Vodafone, 2009) (Flatrate To Go, 2009) in Table 1 as a reference, the total power consumption of base stations in Germany is between 760 GWh and 3040 GWh per year meaning that 410.000 to 1.645.000 tons of carbon dioxide is emitted in Germany per year[2] (BDEW, 2008). For 2020, (The Climate Group, 2008) estimates a carbon emission of 349.000.000 tons for the telecommunication infrastructure, whereas the mobile environment will contribute with 51%. (Remark: In 2002, the carbon emission of the telecommunication infrastructure was 151.000.000 tons and the mobile environment covered 43% of it.) With the optimizations being done in the mobile network, we estimate a reduction of the operating time of network components up to 40% – 60%, i.e., a reduction of the carbon dioxide emission up to 328.000 to 1.974.000 tons per year.

6 CONCLUSIONS

The objective of the project *Communicate Green* comprises the development of an adaptive and context-aware power management. The decision and adaptation algorithms that are going to be implemented throughout the project, are going to save energy in mobile networks by dynamically de- and reactivating network components and by reconfiguring the network to user needs. Optimizations will be proposed for single and heterogeneous radio technologies as well as for the core network. Our part of the project concentrates on the development of a context entity that collects and processes contextual information from various context sources in order to build the data basis for decision calculations. The expected results as listed above show that the projects approach is innovative and promises an enormous reduction of the power consumption in future mobile networks.

[1]Numbers extracted from data sheets of the companies Ericsson, Motorola, Nokia Siemens Networks and Huawei

[2]Calculation is based on the average value for carbon dioxide emission in Germany 2007, 541 g/kWh

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