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Smartphones Network Connections Power-Aware Multiple Wireless Interfaces

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Abstract: The premise of this resesrch is that current smartphones power saving strategies can be improved towards saving more power and or gain more user satisfaction only if they start following “preventive” and or “user customized” power saving plans. This resesrch develops a number of preventive power saving strategies which help in saving the battery power without the need of using the power of the same battery for detecting abusers (detective strategies). Although, the focus of this work is on power-aware smartphone network wireless connections, other layers such as application, operating system and hardware layers of smartphones are of important interest to optimize our solutions across all layers. Smartphones can’t work as stand-alone devices. They have to connect to a wireless network to do something useful. Bending network availability smartphones use on-demand strategy to connect to a specific network. This comes with a great deal of power consumption cost in addition to the cost of using the network if any. How to optimize this on-demand networking strategy using “preventive” and or user “customized” power saving plans acros multiple layers and wireless interfaces is the research of this study. A set of “preventive” customized power-aware connecting strategies are offered. Some of them are evaluated experimentally.

Key words: Power, wireless, saving, network layers, detective strategies, specific network

INTRODUCTION

Current smartphones can be thought of as “developed versions” of the earlier portable handheld devices. Figure 1 shows the four basic layers of an average smartphone and prominent researches implemented on each layer targeting reducing power consumption. We will review previous research done in mobile phones power saving particularly the energy aware techniques implemented on the network layer of Fig. 1. Then we will expose the weaknesses of these related research work to clarify the problems of this sallow layer oriented approach. We will then motivate four issues towards network connections power consumption optimization: preventive/detective, customized (not one size fits all but may be for specific type of users/applications/usage), cross-layers and across multiple wireless interfaces plans. On the network layer of Fig. 1, approaches for reducing energy consumption focus mainly on ensuring predictable delivery of data packets (Perez-Torres and Torres-Huitzil, 2012) and supporting computation off-loading (Flinn *et al*., 2001) or protocol design for lowering energy consumption (Yuan and Nahrstedt, 2003).

Some of the approaches on network layer provide concrete energy-saving techniques while other approaches serve as pre-requisites by providing reliable estimates of energy consumption for various tasks in order to enable more energy-efficient task scheduling and execution. Predictable delivery of data packets focuses primarily on ensuring that data packets are received by mobile devices in bursts, so that, the network interface card can be transitioned to low-energy consumption sleep mode between those bursts. One approach uses a transparent proxy between mobile devices and remote locations as a means to control traffic and ensure predictable delivery. The proxy buffers data to create bursts of packets, dynamically generates optimal transmission schedules and maintains separate connections to the client and the server (Anonymous, 2010). Energy savings through this approach are reported to be within 10-15% of the optimal case without any significant loss of data transmission reliability (Anonymous, 2018).

A different approach uses a server-side proxy that groups data packets in bursts, schedules them and informs a client-side proxy of the schedule, so that, the mobile device’s wireless network card can be transitioned to sleep mode between the bursts (Yuan and Nahrstedt, 2003). Empirical evaluations of the proposed approach show that it can reduce the amount of energy required for data transmission by up to 83% while also supporting multiple clients that share a single wireless access point. However, the empirical results also show that the approach can result in a perceived loss of performance for some applications as media players are noted to reduce

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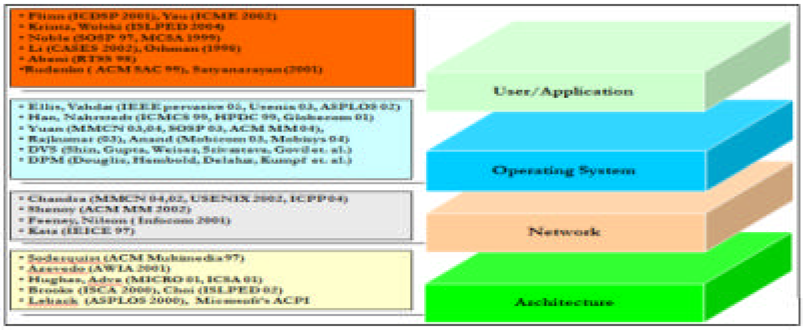

Fig. 1: Gupta's abstract architecture of layers for a standard communication portable device (Sameh and Almasri, 2018)

video fidelity, in response to perceived delays due to the inactive time between bursts. This downside is considered to be avoidable if media players are made aware of the energy-saving approach and offer configurable settings to handle it without loss of performance.

In both of the above cases, packet loss is negligible or non-existent. Consequently, both approaches can be considered to focus essentially on lowering energy consumption through a more efficient use of resources without actually compromising on quality of service. Nevertheless, it is unclear whether this is possible without further integration of energy-aware mechanisms at different layers, beyond the network layer.

Approaches to lowering energy consumption through network protocol design and controlling network traffic as in the examples above are supported by studies of how much energy is actually consumed by wireless network cards in different situations. For example, a study of exact energy consumptions in different scenarios provides concrete ways of calculating the energy required for sending, receiving and even discarding data packets on a wireless network card in an ad-hoc network environment (Yuan and Nahrstedt, 2003). Energy consumption was determined for different types of operations (sending, receiving and discarding traffic), different packet size (large and small), different operation modes (promiscuous or not) and different types of traffic (broadcast and point-to-point). In all cases, the energy consumed was calculated based on direct measurements of input voltage and current draw, resulting in a set of linear equations that can be used to calculate the energy required in a given situation.

A different network layer approach to lowering energy consumption is to off-load computational tasks that are energy-intensive. This approach is supported by utilities that provide accurate and computationally efficient estimates of energy consumption for a given task when executed locally as well as when off-loaded to a remote location. For example, NWSLite is such a utility designed, especially for mobile devices as a scaled down version of a dynamic prediction toolkit for grid applications (Flinn *et al*., 2001). An empirical evaluation of NWSLite compares it to other existing prediction utilities such as NWS, LSQ and RPF. The results show that NWSLite has similar prediction accuracy to NWS and better prediction accuracy than both LSQ and RPF overall for different types of applications and operations.

Limitations of existing approaches: Despite their usefulness, existing approaches for better management of energy resources on mobile devices have several significant limitations. The following discuss such limitations and describe how the current study provides solutions to them.

The main limitation of the approaches is that they fail to address energy consumption concerns at the whole system level. Instead, they focus solely on the concerns that are relevant at one or two system levels while either ignoring what happens on other levels or at best, making unverified assumptions about it. For example, approaches at the user-application layer focus on adaptive algorithms, measuring and profiling applications and adaptive scheduling and configuration (Yuan and Nahrstedt, 2003; Datta *et al*., 2013; Chakraborty and Yau, 2002; Perez-Torres and Torres-Huitzil, 2012; Yuan *et al*., 2003; Bonino and Corno, 2008). However, none of those approaches directly takes into account relevant characteristics on other levels such as available options for computational offloading or network traffic and protocol design on the network layer.

Few existing approaches try to address this limitation to some extent. For instance, the currency approach models energy resources at the system level rather than focusing solely on a single layer. However, energy consumption and the different concerns of the various system levels are not all considered. Similarly, the GRACE-1 approach aims to provide the means for energy-aware adaptations at the system level (Flinn *et al*., 2001; Yuan *et al*., 2003; Abogharaf and Naik, 2013).

However, GRACE-1 takes into account only a limited set of energy concerns and potential adaptations, focusing mainly on those at the operating system layer and a subset of those at the network and user-application layers.

Another limitation of existing approaches is that they tend to be device centric, meaning that they focus explicitly on the energy concerns that can be observed on one specific device such as the network adapter. For example, several approaches propose to lower energy consumption of wireless network adapters by ensuring predictable delivery of data packets (Anonymous, 2018; Yuan and Nahrstedt, 2003). However, such device centric approaches fail to consider wider issues that can be observed only at a system level. Such issues include for instance network congestion and mobility requirements of the user which can both affect energy consumption and the type of adaptations that are acceptable.

The device centric characteristic of existing approaches also means that most adaptations are essentially reactive: changes are made in response to observed inefficiencies in energy use but there is little done to prevent energy issues in the first place. For example, several approaches on the user-application layer rely on measurements and profiling of applications to decide on the most efficient scheduling and configuration (Yuan and Nahrstedt, 2003; Anonymous, 2018; Abogharaf and Naik, 2013). However, this approach does not offer any opportunity for preventing inefficient energy use by various applications.

Overall it can be argued that the main limitation of existing approaches is the fact that they lack a generalized global framework that would enable co-ordination between different system layers, a system-centric rather than device-centric approach to energy management and a pro-active adaptation to different situations (preventive). This is partially due to the fact that most approaches focus on providing very specific improvements such as more efficient functioning of the wireless network adapter or more efficient scheduling and configuration of applications (Perez-Torres and Torres-Huitzil, 2012; Yuan and Nahrstedt, 2003; Anonymous, 2018; Abogharaf and Naik, 2013). However, despite the benefits of those specific improvements, they cannot deliver their full benefits unless they are integrated together in a generalized global framework that considers every relevant aspect of a given system.

The few existing attempts towards a generalized global framework do not fully address this limitation as they do not model the system itself but rather some specific approach to energy resource management. For instance, the GRACE-1 Model forces a hierarchical model of adaptations that do not take into account specific characteristics of the system of all levels (Yuan and Nahrstedt, 2003; Abogharaf and Naik, 2013). Similarly, the currency framework effectively models mainly energy requirements and available energy resources but not specifically the different relevant characteristics of system components on the various levels. Consequently, both GRACE-1 and currency can help improve energy management but still fail to provide the generalized global framework that is needed to ensure that the energy management is done at a system level, addressing the concerns at all system levels, taking into account the characteristics of each individual device as well as those of the system as a whole and supporting a pro-active adaptation to different situations.

In each sub-section, we will stress at four issues regarding network connectivity: preventive/detective, customized (not one size fits all but may be for specific type of users/applications/usage), cross layers and across multiple wireless interfaces.

MATERIALS AND METHODS

Power-aware network connections for smartphones with multiple wireless interfaces: Smartphones can connect to the “Cloud”, to a WiFi acess point, to cellular tower, Optical Broadband, 3G, 4G, LTE, Passive Optical Network (PON), Satellite GPS, other mobile devices, Bluetooth network, wireless Gateway, opportunistic networks, etc. In the following subsections we demonstrate how to embrace power awareness in such connections individually and in a parallel. Then we will demonstrate experimentally one scenario as an experimental proof.

Smartphone connecting to a “Cloud”: With the growing maturity of the cloud computing paradigm, clouds are increasingly used for the delivery of complex multimedia services, rather than just simple infrastructure offers. A popular example of such services is cloud gaming where video games are executed in the cloud and delivered to a (mobile) client via. the internet. While cloud gaming shifts the computationally complex and energetically expensive task of rendering the game content from the client to a server it also requires the constant, energy-demanding use of wireless interfaces. By Sameh and Almasri (2018), researchers examined this trade-off based on a custom-designed mobile cloud gaming system called “MCGS.KOM”. In their experiments which involve different mobile phones, varying game complexities and various streaming quality levels indicated that cloud gaming may facilitate substantial energy saving between 12 and 38% on the mobile device if WLAN is used as network connection type. This technique can be further enhanced if it considers in addition to player "customization", "Preventive" planning, "Across multiple wireless interfaces" implementations and defiantly optimizing across operation system and hardware layers.

Smartphone connecting to WLAN: Battery performance of a smartphone is high priority for smartphone users. Wireless networking such as WEB browsing, SNS, contents download consumes one third of energy consumption of smartphone use case. As 3G-4G interface spends much power it may recommend that using WLAN is more efficient for battery life. The various power-saving methods for WLAN have been well understood but such solutions need modification of network infrastructure. Therefore, it is difficult to adequate current system. In Datta *et al.* (2013) researchers presented a cross-layer power save method which can coexist with related works. The proposed method controls TCP-acknowledgement transmission depends on wireless channel quality and network quality. This method does not need any modification to current infrastructure and can save battery power without network performance degradation. This technique can be further enhanced if it considers in addition to the cross layers/networking the two other issues of "Preventive" planning and customization through each layer.

Smartphone connecting to cellular network: One of the most influencing factors on the overall end-user perceived quality from applications and services, i.e., QoE, running on the smartphones is their limited battery life. Particular cloud-based applications/services on the smartphone with a constrained battery life might consume high energy even when the smartphone is in screen-off state. The cellular radio module of the smartphone is one of the most power-consuming components which depends on the running application's information polling characteristics that eventually cause the radio module to toggle occasionally between the cellular data energy states even during a sleep state. By Chakraborty and Yau (2002), resesrchers investigated the energy consumption of a set of applications that tend to retain up-to-date information via. aggressive polling patterns. They showed that limiting the network traffic and increasing the resource utilization efficiency amongst the applications and services can highly reduce the total energy consumption. They controlled the network activity of a smartphone with different cellular data-enabled and data-disabled durations at the screen-off state. First, they run controlled-lab energy measurements to have a ground truth on the power consumption patterns of a set of cloud-based popular applications/services and next they conduct a subjective study with their proposed solution (ExpC02), to understand first the user behavior on the smartphone and then present how the reduced polling intervals of applications and notifications influence the end-user perceived quality. They indicate that ExpC02 has a potential to save energy. This technique can be further enhanced if it considered in addition to "customization" and its "Preventive" planning, extending implementation through "Across multiple wireless interfaces" and defiantly optimizing across operation system and hardware layers.

Smartphone connecting to "Integrated PON-4G wireless optical broadband access network" wired Passive Optical Networks (PON)+4th Generation (4G) wireless networks: Exponential growth in the volume of wireless data, boosted by the growing popularity of mobile devices such as smartphone and tablets has forced the telecommunication industries to rethink the way networks are currently designed and to focus on the development of high-capacity mobile broadband networks. In response to this challenge, researchers have been working toward the development of an integrated wireless optical broadband access network. Two major candidate technologies which are currently known for their high capacity as well as Quality of Service (QoS) for multimedia traffic are Passive Optical Networks (PON) and 4th Generation (4G) wireless networks. PON is a wired access technology, well known for its cost efficiency and high capacity whereas 4G is a wireless broadband access technology which has achieved broad market acceptance because of its ease of deployment, ability to offer mobility and its cost efficiency. Integration of PON and 4G technologies in the form of wireless-optical broadband access networks, offers advantages such as extension of networks in rural areas, support for mobile broadband services and quick deployment of broadband networks. These two technologies, however have different design architectures for handling broadband services that require quality of service. For example, 4G networks use traffic classification for supporting different QoS demands whereas the PON architecture has no such mechanism to differentiate between types of traffic. These two technologies also differ in their power saving mechanisms. By Perez-Torres and Torres-Huitzil (2012), researchers proposed a service class mapping for the integrated PON-4G network which is based on the M/G/1 queuing model. They also proposed a class-based power saving mechanism which significantly improves the sleep period for the integrated optical wireless unit without compromising support for QoS. Results indicate that their proposed class-based power saving scheme reduced power consumption by up to 80% and maintained the QoS within the requirements of the service level agreement. This technique can be further enhanced if it considers in addition to "customization", "Preventive" planning, "Across multiple wireless interfaces", optimizing across operation system and hardware layers.

Smartphone connection in "Areas with bad receptions" cellular and WiFi networks: Despite of all the advances in smartphone technology in recent years, smartphones still remain limited by their battery life. Unlike other power hungry components in a smartphone, the cellular data and WiFi interfaces often continue to be used even when the phone is in its idle state in order to accommodate background (necessary or unnecessary) data traffic produced by some applications. In addition, bad reception has been proven to greatly increase energy consumed by the radio which happens frequently when smartphone users are inside buildings. By Flinn *et al.* (2001) researchers present a Short message service Push based Service (SPS) system to save unnecessary power consumption when smartphones are in idle state, especially in bad reception areas. First, SPS disables a smartphone's data interfaces whenever the phone is in idle state. Second, to preserve the real-time notification functionality required by some apps such as new email arrivals and social media updates when a notification is needed, a push server will deliver a wakeup text message to the phone (which does not rely on data interfaces) and then SPS enables the phone's data interfaces to connect to the corresponding server to retrieve notification data via. the normal data network. Once the notification data has been retrieved, SPS will disable the data interfaces again if the phone is still in idle state. Flinn *et al.* (2001) have developed a complete SPS prototype for Android smartphones. Their experiments showed that SPS consumes less energy than the current approaches. In areas with bad reception, the SPS prototype can double the battery life of a smartphone. This technique can be further enhanced if it considers in addition to "customization" and "Preventive" planning, "Across multiple wireless interfaces" by applying the same technique to other types of networking, defiantly optimizing across operation system and hardware layers.

Smartphone use of speed-control; Energy-delay tradeoff: Many smartphone applications, e.g., file backup are intrinsically delay-tolerant, so that, data processing and transfer can be delayed to reduce smartphone battery usage. In the literature, these energy-delay tradeoff issues have been addressed independently in the forms of Dynamic Voltage and Frequency Scaling (DVFS) problems and network selection problems when smartphones have multiple wireless interfaces. By Yuan and Nahrstedt (2003) researchers optimize the CPU speed and network speed to determine how much more energy can be saved through the joint optimization when applications can tolerate delays. They proposed a dynamic speed scaling scheme called "Speed control" that jointly adjusts the processing and networking speeds using four controls application scheduling, CPU speed control, wireless interface selection and transmit power control. Through invoking the "Lyapunov drift-plus-penalty" technique, the scheme is demonstrated to be near optimal because it substantially reduces energy consumption for a given delay constraint. This study is the first to reveal the energy-delay tradeoff relationship from a holistic perspective for smartphones with multiple wireless interfaces, DVFS and multitasking capabilities. The trace-driven simulations based on real measurements of CPU power, network power, WiFi/3G throughput and CPU workload demonstrated that speed control can reduce battery usage by more than 42% through trading a 10 min delay when compared with the same delay in existing schemes moreover, this energy conservation level increases as the WiFi coverage extends. This technique can be further enhanced if it considers in addition to "customization" and optimizing across operation system and hardware layers, other issues "Preventive", "Across multiple wireless interfaces".

Smartphone intelligently switching between GPRS and WiFi: Various hardware components of smartphones such as CPU, GPS, screen and wireless interfaces, can easily run out of the battery's power. Therefore, power consumption has become the bottleneck for smartphone's prosperity. In order to reduce energy consumption of smartphones and extend the lifetime of battery, researchers by Anonymous (2018) developed an energy management system based on Android operating system, called "Phone Joule". It switches between GPRS and WiFi wireless networks, monitors and manages the energy consumption of smartphone in an intelligent manner. Six different power-saving modes were provided for users to easily manage the power consumption of their smartphones. Furthermore, the status of the smartphone such as battery information and usage of CPU and memory can be retrieved in real time. This technique can be further enhanced if it considers in addition to "customization", use of "Preventive" planning and acting on "Across multiple wireless interfaces", optimizing across operation system and hardware layers.

Smartphone connecting to a Collaborative Mobile Cloud (CMC): A Collaborative Mobile Cloud (CMC) which consists of several smartphones offers one potential solution for reducing the energy consumption at the terminal side in the downlink. In addition as RF signal can carry both information and energy simultaneously, the induced Simultaneous Wireless Information and Power Transfer (SWIPT) is also capable of prolonging the battery of smartphones. By Abogharaf and Naik (2013), the power allocation algorithm for CMC with SWIPT is formulated as a non-convex optimization problem which takes into account the baseband circuit power consumption, RF transmit and receiver power, harvested energy and the minimum required data rate. Accordingly by exploiting the properties of nonlinear fractional programming, the formulated non-convex optimization problem of which objective function is in fractional form is transformed into an equivalent optimization problem having an objective function in subtractive form and is able to be solved in dual domain. Simulation results demonstrated that the proposed user scheduling and resource allocation algorithms can achieve significant energy saving performance. This technique can be further enhanced if it considers in addition to "customization" and "Optimization", other issues of "Preventive" planning, "Across multiple wireless interfaces" are important for further enhancement.

Smartphones use different connection modes (e.g., long and short DRX discontinuous receptions): The cellular network traffic growth is witnessed both in volume and diversity in terms of traffic characteristics. Among the different types of traffic, there is prominent increase in background type of data due to popularity of applications like Facebook, Skype, e-mail clients etc which keeps exchanging data with corresponding server, even when the user is not actively using the application. In order to save power consumption of smart phones and for optimal allocation of resources to deserving phones in network by minimum possible signaling traffic, 3GPP LTE specifications have defined mechanisms like connected mode DRX (Discontinuous Reception) which offers two stage of sleep in form of long and short DRX. Since, such diverse type of applications are running in smartphone, the work by Yuan and Nahrstedt (2003), attempts to investigate traffic characteristics of popular applications in Android based smartphones. Due to various reasons, such applications, keep consuming precious bandwidth and battery even when not in active use. Main emphasis is thus provided to study the characteristic of these applications when they are running without user intervention. Since, the diverse range of data characteristics is assumed to be causing drain in User Equipment (UE) battery and overhead in NW signaling this work considers the four issues connection modes and defiantly cross operation system and hardware layers for the user's cooperation. This technique can be further enhanced if it considers in addition to "customization" "Preventive" planning and defiantly optimizing across operation system and hardware layers, "Across multiple wireless interfaces" by applying similar ideas to other types of networking.

Smartphone uses "Mobile offloading solutions" with cellular operators, WiFi service providers and end-users: Searching for mobile data offloading solutions has been topical in recent years. By Zeng *et al*. (2002), researchers presented a collaborative WiFi-based mobile data offloading architecture Metropolitan Advanced Delivery Network (MADNet), targeting at improving the energy efficiency for smartphones. According to their measurements, WiFi-based mobile data offloading for moving smartphones is challenging due to the limitation of WiFi antennas deployed on existing smartphones and the short contact duration with WiFi APs. Moreover, the study showed that the number of open-accessible WiFi APs is very limited for smartphones in metropolitan areas which significantly affects the offloading opportunities for previous schemes that use only open APs. To address these problems, MADNet intelligently aggregates the collaborative power of cellular operators, WiFi service providers and end-users. The researchers designed an energy-aware algorithm for energy constrained devices to assist the offloading decision. The design enabled smartphones to select the most energy efficient WiFi AP for offloading. The experimental evaluation of the prototype on smartphone (Nokia N900) demonstrated that it is able to achieve more than 80% energy saving. Their measurement results also showed that MADNet can tolerate minor errors in localization, mobility prediction and offloading capacity estimation. This technique can be further enhanced if it considers in addition to "customization", "Preventive" planning and "Across multiple wireless interfaces", optimizing across operation system and hardware layers.

Smartphone using lazy video downloading algorithm: Experiments have shown (Yuan *et al*., 2003) that video downloads account for a large portion of the total energy cost of downloading and playing video files. By Yuan *et al*. (2003) researchers presented a novel, energy efficient, purely client-centric video downloading algorithm with three tunable parameters: buffer size, low water mark and socket-reading size. By means of implementation of the algorithm on a smartphone and measurements of the actual energy cost of downloading video files, they showed the impacts of the three parameters on the energy cost of video downloads. By tuning the buffer size, low water mark and socket-reading, they observed energy savings of 60, 64 and 63%, respectively. This technique can be further enhanced if it considers in addition to "customization" the three other issues "Preventive" planning for parameter setting, "Across multiple wireless interfaces" of various types and defiantly optimizing across operation system and hardware layers rather than on the application layer alone.

Smartphone using lazy video downloading algorithm: Researchers by Yuan and Nahrstedt (2003) proposed "E$PA", an adaptive LTE/WiFi network interface activation algorithm with supporting system design and multi-attribute cost function for smartphones file transfer services (e.g., downloading a movie file). E$PA's cost function incorporates battery life (energy), data usage quota ($) and expected file transfer completion time (performance) simultaneously and is motivated by the growing sensitivity of today's smartphone users to these attributes. Each time the individual attributes are calculated and updated, E$PA selects one of the three modes that minimizes the overall cost: activation of both LTE and WiFi interfaces for parallel data transfer; LTE interface activation only or WiFi interface activation only. The primary benefit of the E$PA is that it enables the smartphone to always operate in the "best" mode without the need for user's manual control the energy saving mode if the remaining battery energy is becoming nearly depleted the cost saving mode if the remaining data quota is almost running out or the maximum throughput mode if remaining data quota and battery life are both sufficient. The multi-attribute cost model also takes into account the overheads (delays and energy consumption) associated with network interface turn-on/off and switching as they impact the estimations of both performance (transfer time) and energy (battery life) attributes. Simulation results showed that E$PA indeed chooses the "best" operational mode by maintaining dynamic balance among transfer time, energy consumption and service charge. This technique can be further enhanced if it considers optimizing across operation system and hardware layers instead of only at the application layer.

Smartphone connecting to WLAN-Opp (Opportunistic network) an 802-11 based protocol: Opportunistic networking enables many appealing applications including local social networking, communication in emergency situations and circumventing censorship. The increasing penetration of smartphones should in theory, foster opportunistic networking. In practice, current candidate technologies for opportunistic networking such as WiFi ad-hoc, Bluetooth and WiFi direct are either not available on current smartphones or require undesired user interaction to establish connectivity. To overcome these shortcomings, researchers by Flinn *et al.* (2001) proposed WLAN-Opp for smartphones. This IEEE 802.11-based technology leverages the tethering mode of smartphones, a feature originally used to share internet access which allows smartphones to become WLAN-based access points that provided networks for other smartphones operating as stations. The transitions between WLAN-Opp access point and station mode are randomized as a function of the number of other co-located networks and stations and depend on duty cycling intervals. They optimized the probabilistic operations in a simulation study and provided a parametrized implementation of WLAN-Opp for out of the box smartphones. By replaying real contact traces in simulation, they fond that WLAN-Opp can utilize up to 80% of the contact time while saving up to 90% of the energy WiFi ad-hoc would consume. This technique can be further enhanced if it considers in addition to "customization" and "Preventive" planning, "Across multiple wireless interfaces", optimizing across operation system and hardware layers the tethering process.

Smartphone uses user profile for future battery usage prediction: Personalized power management in mobile devices is a critical issue in handling the diversity of smartphone usage. In particular, usage prediction is important for the efficient use of remaining battery capacity. By Yuan and Nahrstedt (2003), they proposed a system that predicts the amount of battery usage required in the future. The key insight is that a high degree of correlation exists between battery usage and a user's movements. They designed an everyday location monitoring system that only uses cell-tower connections without additional energy consumption. The technical challenge is eliminating the ping-pong effect in a series of cell-tower transitions to determine the mobility status, especially with limited access to the list of neighboring cell towers. They construct a graph from the sequence of recorded cell towers and recognize the points of interest using a partial clique graph. They use the Markov predictor to estimate the required battery level depending on the user's movements. They have demonstrated the accuracy of battery usage prediction using real traces of participants collected over a period of 4 weeks. The result shows that the proposed system correctly predicts the battery usage of smartphones with an 8.1±7.5% margin of error. This technique can be further enhanced if it considers in addition to "customization" and "Preventive" planning, "Across multiple wireless interfaces" by repeating their same idea across other network types and defiantly optimizing across operation system and hardware layers in addition to the current application layer.

Smartphone connecting to other smartphone users autonomous networking: Anonymous (2018) presented the design principles, implementation and evaluation of "SPONET", a framework that has been specifically developed for spontaneous networking among smartphone users. SPONET has four distinct objectives, providing a rich context for location-aware networking, robust cognitive networking, extensibility with various routing protocols and a convenient programming interface for delay-tolerant applications. The key technical challenges are therefore, unsupervised place learning, network construction without user intervention and a networking policy with low complexity. Anonymous (2018) have designed a place-learning algorithm using the properties of scanned WiFi access points to identify meaningful places. SPONET provided dynamic neighbor discovery and data exchange mechanisms for autonomous networking. They have implemented SPONET on Android-based, off-the-shelf smartphones without any adaptation of their networking architecture. Experimental results showed that the proposed system is indeed acceptable as a framework for various delay-tolerant applications in smartphones. This technique can be further enhanced if it considers in addition to "customization" and its "Preventive", optimizing across operation system and hardware layers in addition to the application layer.

Smartphone connecting to a cloud: Employing Mobile Cloud Computing (MCC) to enable mobile users to acquire benefits of cloud computing by an environmental friendly method is an efficient strategy for meeting current industrial demands. However, the restrictions of wireless bandwidth and device capacity have brought various obstacles such as extra energy waste and latency delay when deploying MCC. Addressing this issue, researchers by Abogharaf and Naik (2013) have proposed a dynamic energy-aware cloud let-based mobile Cloud Computing Model (DECM) focusing on solving the additional energy consumptions during the wireless communications by leveraging Dynamic Cloud Lets (DCL)-based model. In their work they examined the model by a simulation of practical scenario and provided solid results for the evaluations. Their main contributions are twofold. First, this study is the first exploration in solving energy waste problems within the dynamic networking environment. Second, the proposed model provides future research with a guideline and theoretical supports. Thier technique can be further enhanced if it considered in addition to "customization" within the dynamic networking environment the three other issues "Preventive" planning, "Across multiple wireless interfaces" by applying this same idea to other types of networking in addition to the "Cloud" and defiantly optimizing across operation system and hardware layers to further enhance their Cloudlets Model.

Smartphone connecting to wireless opportunistic forwarding networks: During emergency situations, the use of mobile devices and wireless opportunistic networks as a solution of destroyed or overused communication networks are vital. In these cases, the fast and reliable delivery of emergency information, together with the use of energy-efficient communication mechanisms are required. By Yuan and Nahrstedt (2003), researchers proposed "PropTTR and PropNTTR", a set of forwarding mechanisms for wireless opportunistic networks in emergency scenarios that provide a high message delivery ratio together with a low energy consumption. They have set up a testbed used to compare the performance and energy-efficiency of their proposals with two other significant forwarding methods. They presented the results of this analysis comparison in terms of message delivery ratio, delivery cost, latency and energy consumption, showing the improvements. This technique can be further enhanced if it considers in addition to "Preventive planning" the three other issues "Across multiple wireless interfaces" by applying the same forwarding mechanisms over other types of networking and defiantly optimizing across operation system and hardware layers not only at the application level only.

Smartphone streaming over 3G and LTE networks: Energy consumption of mobile devices is a great concern and streaming applications are among the most power hungry ones. Flinn *et al.* (2001) evaluated the energy saving potential of shaping streaming traffic into bursts before transmitting it over 3G and LTE networks to smartphones. The idea is that in between the bursts, the phone has sufficient time to switch from the high-power active state to low-power states. They investigate the impact of the network parameters, namely inactivity timers and discontinuous reception on the achievable energy savings and on the radio access network signaling load. The results confirm that traffic shaping is an effective way to save energy, even up to 60% of energy saved when streaming music over LTE. However, they noted large differences in the signaling load. LTE with discontinuous reception and long inactivity timer value achieved the energy savings with no extra signaling load whereas non-standard Fast Dormancy in 3G can multiply the signaling traffic by a factor of ten. This technique can be further enhanced if it considers in addition to "customization", "Preventive Planning" and "Across multiple wireless interfaces", optimizing across operation system and hardware layers in addition to the application layer.

Smartphone energy-aware offloading mobile code to the infrastructure: The study by Yuan and Nahrstedt (2003) presented "MAUI", a system that enables fine-grained energy-aware offload of mobile code to the infrastructure. Previous approaches to these problems either relied heavily on programmer support to partition an application or they were coarse-grained requiring full process (or full VM) migration. MAUI uses the benefits of a managed code environment to offer the best of both worlds: it supports fine-grained code offload to maximize energy savings with minimal burden on the programmer. MAUI decides at runtime which methods should be remotely executed, driven by an optimization engine that achieves the best energy savings possible under the mobile device's current connectivity constrains. In their evaluation, they showed that MAUI enabled: a resource-intensive face recognition application that consumes an order of magnitude less energy, a latency-sensitive arcade game application that doubles its refresh rate and a voice-based language translation application that bypasses the limitations of the smartphone environment by executing unsupported components remotely. This technique can be further enhanced if it considers in addition to "customization" the three other issues "Preventive" by planning ahead of runtime the off-loading decisions, "Across multiple wireless interfaces" by applying the same ideas for other types of networking (in addition to the cloud) and defiantly optimizing across operation system and hardware layers not only off-loading at the application layer.

RESULTS AND DISCUSSION

Previous research has shown that the strength of the WiFi signal is strongly related to the amount of power consumption of the smartphone battery (Flinn *et al*., 2001). So, the more strong the WiFi signal, the more energy efficient it is for the smartphone battery. When the WiFi signal strength is low, the amount of energy stored in the smartphone battery will be consumed fast because the phone will keep on trying to communicate with the access point that is providing this weak signal and to keep on sending and receiving data through this weak communication. So, the weaker the WiFi signal, the more energy is consumed to transmit and receive data. If a smartphone is under a strong WiFi coverage area and is connected to this strong WiFi then it is the total opposite of the previous point, meaning that the battery of the smartphone will not consume its energy fast, since, it does not need to consume much power trying to transmit and receive power through the strong connection.

WiFi signal strength and battery life: If a smartphone with its WiFi feature ON spends a lot of time away from a wireless connection, the phone will spend a lot of energy searching for a wireless access point which will cause the amount of energy on the battery to be consumed fast. In this case many recommendations were given towards disabling the WiFi feature if it is not being used in order to save more of the battery life (Flinn *et al*., 2001).

Table 1 of a previous study made by Rajesh K. Gupta and Prasant Mohapatra shows the difference in the average power drawn in different states of a phone that is using a WiFi connection with different RSSI (Abogharaf and Naik, 2013).

The table shows that the amount of power consumed under a WiFi connection with high RSSI (-35 to -50 dBm) on both "On Call" and "In Standby" states is lower than the amount of power consumed under a WiFi connection with a low RSSI (-65 to -77 dBm) which proves the above part.

Showing only WiFi connections with strong RSSI during WiFi search: Once the WiFi feature gets activated on any smartphone equipped with a WiFi radio, 5 the smartphone

Table 1: Difference in the average power drawn in different states of a phone that is using a WiFi connection with different RSSI

802.11a Voltage	#of Aps	Currant drawn on cell (mA) 4.2V	3.7V	Currant drawn in standby (MA) 4.2V	3.7V	Currant drawn out of network (mA) 4.2V	3.7 V
High RSSI	1	117.4	129.9	16.2	18.6	12.4	16.1
-35 to -50dBm	2	115.5	126.1	16.1	18.2	12.4	18.1
Low aignal strength	1	119.3	126.1	24.0	26.7	12.4	16.1
-66 to -77dBm	2	114.2	126.1	21.0	24.5	12.3	18.1

will start automatically searching for wireless connections and will sort the available connections as per to the strength of each connection which actually gives the user the freedom to select the connection that he/she prefers regardless of the effect of each connection on the battery life of the smartphone. The user may try to connect to a WiFi connection just because it is unsecured with a network key, so that, he/she could enjoy free internet access or the user may choose to connect to a certain WiFi connection using his/her smartphone just because it is there without giving a lot of attention to the strength of this network connection.

Since, our general research intention focuses on improving the current techniques used for power saving and power aware applications and going back to chapter four that focused on classifying smartphone users into groups based on the amount of power consumption for the sake of proposing different power saving polices to each different group, the study can propose a new policy when a user activates the WiFi feature on a smartphone and after the smartphone searches for the available WiFi connections. The policy will work on showing the user only connection with strong RSSI and by depending on the previous classification of weak and strong signals that is made by Gupta and Prasant Mohapatra (Abogharaf and Naik, 2013) considering (-35 to -50 dBm) as high RSSI and (-65 to -77 dBm) as low RSSI then it will be possible to show only network connections between (-35 to -50 dBm) to users that are using one of our previously proposed customized power saving modes.

Minimizing discovered WiFi network connections in order to save more power: As all recent smartphones have the WiFi feature embedded. The feature is designed to search and discover signals of as much nearby connections as possible. The process of searching for a WiFi radio on a smartphone covers a certain range in meters. In networking there is a common rule saying that WiFi routers running on 2.4 GHz band can reach up to 46 m indoors and 92 m outdoors in other routers running on 5 GHz bands can reach up to 15 m indoor and 30 m outdoor. The market now has many new technologies of routers that operate on both previously mentioned bands 2.4 and 5 GHz bands. These routers vary in the reaching distances materials that homes or offices are made from or exist in buildings row materials as cement or metal reduce the range of a WiFi network by 25% or more and due to laws of physics, 5 GHz WiFi connections are more susceptible to obstructions than are 2.4 GHz.

Radio signal interference from microwave ovens and other equipment also negatively affects WiFi network range. Because 2.4 GHz radios are commonly used in consumer gadgets, those WiFi connections protocols are more susceptible to interference inside residential buildings. Since, this study focuses on improving power saving techniques on smartphones, the study proposes giving more attention to the amount of energy consumed every time a smartphone searches for a signal through its WiFi radio. The propose is reducing the range of searching that a smartphone WiFi radio covers as per to each different user classification.

From the previous clarification about WiFi bands and ranges the study will not interfere in changing the band of a smartphone WiFi connection, since, each band has its advantages and disadvantages. Since, finally the distance at which someone can connect to an access point varies depending on antenna orientation. So, in case a user activates his/her customized power saving mode, the study proposes reducing the amount of power voltage that is given to the WiFi radio on his/her smartphone. That is because as a phone radiate more electrical energy, the draw on the smartphone battery increases. OEMs attempt to balance this to an acceptable level: too little power and a limited distance, too much and the battery drains quickly. The less power a smartphone outputs, the shorter the signal can travel and the “quieter” a phone becomes when compared to all the others that are operating on the same frequency.

Reducing the range of searching will actually save the amount of power that got wasted during the wide range searching process when the smartphone starts detecting and proposing unwanted connections to a user who needs to get connected to his/her home router which is placed in the room only 5 m away from the smartphone.

Measuring saved energy after minimizing discovered networks by reducing the physical existence of network connections: In the following the experimental study will try to prove our previous idea regarding reducing the number of available networks around a smartphone in order to save more battery. But in this case the amount of power consumed is to be measured when a smartphone tries to search for a network connection and define a network to a user as an “Available Nearby Network” on an area that has either one or many network connections by removing all available networks connection and keeping only one connection available. In another scenario by adding more available network connection aside to the available one. The reason the study didn’t implement this experiment with our previous suggestion of reducing the searching range of a WiFi radio is because of the complicated implementation of the idea from hardware side which is not covered in our study. But in order to mimic this idea and since, the WiFi connection basically stands on two main parties in our study which are the smartphone and the network interface the study preferred to limit the number of available network from the network interface side by manipulating the number of available network connections. The following shows the results on both seniors:

First scenario, only one single nearby network connection available: By placing a smartphone with its WiFi feature deactivated in a 12 m^2 room of an apartment located on a partially constructed new building with only one powered on WiFi dual band router available in the same room, making sure not to have any nearby wireless connections available. Figure 1 shows location of a smartphone and a single router in a 12 m^2 room of an apartment located on a partially constructed new building. As it was achieved in the previous scenario the smartphone had as much deactivated features as possible including cellular data in order to be as accurate as possible with our measurements. After activating the WiFi feature on the smartphone the amount of power that were consumed after 10 sec of activating the feature was measured, the smartphone took 8 sec to find all the four nearby connections of all the available router at the nearby apartments and defines them as "Available nearby networks".

An essential step was to deactivate as many features as possible on the smartphone including cellular data in order to be as much accurate as possible with our measurements. After activating the WiFi feature on the smartphone the amount of power that were consumed after 10 sec of activating the feature is measured, the smartphone took three seconds to find the connection and define it as an "Available nearby network" of the only router available inside the 12 m^2 room. Table 2 shows the amount of energy consumed by the WiFi radio in order to search for a nearby connection with 10 sec running time regardless of the time spent to define it as an "Available Nearby Network", the test was done on a Samsung I9500 running Android OS, V4.2.2 (Jelly Bean), V4.3 with power tutor (Chakraborty and Yau, 2002) application. Table 2 the study deduced that the average power consumption of a smartphone searching for a WiFi signal having only one nearby connection is ~19 mW. Now is to go to our second scenario of applying the same measurements but with adding more nearby wireless connections and see how the smartphone is going to deal with finding each one of them from power consumption point of view.

Second scenario, more than one nearby network connections available: In this case the smartphone was kept as it was with its WiFi feature deactivated in a 12 m^2 room of an apartment located on a partially constructed new building with only one powered on WiFi dual band router available in the same room. At the same time more than one router were placed in three more nearby apartments as the following diagram shows Fig. 2, location of a smartphone and a router in a 12 m^2 room of an apartment with three more routers fixed in three nearby apartments located on a partially constructed new building. Table 3 shows the amount of energy consumed by the WiFi radio in order to search for a number ofnearby connections with 10 sec running time regardless of the time spent to define them as "available nearby networks", the test was done on a Samsung I9500 running Android OS, V4.2.2 (Jelly Bean),V4.3 with power tutor application (Fig. 3). Table 3 the results shows that the average power consumption of a smartphone searching for a WiFi signal having only one nearby connection is ~47 mW. This

Table 2: Amount of energy consumed by the WiFi radio in order to search for a nearby connection with 10 sec running time having only one network connection available

Stage (with only one nearby connection available)	Average consumption (mW)
WiFi feature deactivated	~ 573
After 10 sec of activating the WiFi feature	~ 592

Table 3: Amount of energy consumed by the Wi-Fi radio in order to search for a nearby connection with 10 sec running time having more than one network connections available

Stage (with four nearby connection available)	Average consumption (mW)
WiFi feature deactivated	~ 573
After 10 sec of activating the WiFi feature	~ 62

Fig. 2: Location of a smartphone and a router

Fig. 3: Amount of energy consumed by the WiFi radio in order

CONCLUSION

Smartphones can connect to the "Cloud", to a WiFi acess points, to cellular towers, Optical Broadband, 3G, 4G, LTE, Passive Optical Network (PON), Satellite GPS, other mobile devices, Bluetooth network wireless gateway, opportunistic networks, etc. In this study we have investigated how to optimize smartphone's on-demand networking access to any of the above networks using "preventive" and or user "customized" power saving plans across multiple layers and wireless interfaces. A set of "preventive" customized power-aware connecting strategies are offered. Some of them are evaluated experimentally. We have demonstrated how to embrace power awareness in such connections individually and in a parallel. In each specific scenario, we have stressed on four issues regarding network connectivity: preventive/detective, customized (not one size fits all but may be for specific type of users/applications/usage), cross layers and across multiple wireless interfaces. Then we have demonstrated experimentally couple of scenarios as an experimental proof.

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