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OPTIMIZING MOBILE APP PERFORMANCE THROUGH ADAPTIVE RESOURCE MANAGEMENT

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Abstract

The article discusses methods of adaptive resource management of mobile applications, including dynamic distribution of processor time, memory and network resources. An analysis of existing approaches is conducted, an architecture of an adaptive resource manager is proposed that provides a balance between performance and energy consumption. The experimental results show that the implementation of adaptive algorithms allows reducing the response time of applications by 15-25% and reducing memory consumption by 10-18%.

Keywords: Mobile applications, performance optimization, adaptive resource management, energy consumption, dynamic allocation.

Introduction

The scientific novelty of the article is that a new architecture of an adaptive resource manager for mobile applications has been proposed and implemented, combining the dynamic distribution of processor time, memory, and network resources into a single management system. Unlike existing approaches that optimize resources separately, the developed adaptive algorithm provides an automatic balance between performance and energy consumption in real time.

The rapid growth of the mobile ecosystem, as evidenced by the presence of more than 3 billion apps on «Google Play Store», emphasizes the relevance of the problem of optimizing the performance of mobile applications [1]. As functionality increases, the load on device resources (processor, memory, battery) also increases, which negatively affects the user experience.

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Poor mobile app performance results in high CPU usage, excessive memory consumption, and rapid battery drain. Research shows that more than 50% of users uninstall apps for these reasons. This makes resource optimization a key aspect in modern app development.

Optimizing the performance of mobile applications is a complex task that involves resource management, energy consumption, networking, and improving the user experience. In recent years, various methods and approaches have been developed to address these issues.

Existing optimization methods can be classified by the type of resource management:

- static resource management. This method assumes pre-set resource usage parameters. Its main disadvantage is limited flexibility in the face of changing loads.
- dynamic resource allocation. This approach allows adapting the redistribution of resources depending on the current operating conditions of the application [2]. This ensures more efficient use of the available device resources.
- use of cloud technologies. This method involves transferring resource-intensive computing tasks to the cloud. This allows you to unload the mobile device and significantly increase the performance of the application, especially for complex operations.
- integration with network infrastructure. Optimization of network interaction of the application with different types of networks (3G , 4G , 5G , Wi - Fi) is aimed at reducing delays and increasing overall performance.

Modern research increasingly focuses on the use of machine learning and adaptive strategies. These methods allow the application behavior to be dynamically adjusted depending on current conditions, which contributes to more efficient use of resources and an improved user experience. Adaptive approaches provide the flexibility needed to deal with the uncertainty inherent in the mobile environment.

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Table 1 - Overview of key studies

No.	Main research topics	Notes
1	Optimization methods , including dynamic resource allocation [3].	A systematic review of existing methods for optimizing mobile application performance.
2	Mobile application performance optimization techniques , including power and memory management [4] .	A systematic review of mobile application performance optimization techniques.
3	Strategies for testing and optimizing the performance of mobile applications, including network performance and energy management [5].	A practical guide to testing and optimizing the performance of mobile applications.
4	Dynamic resource allocation techniques for cost and performance optimization in multi-cloud environments [6].	Application of dynamic resource allocation methods in multi-cloud environments.
5	Architectural methods and optimization strategies for dynamic resource allocation in edge computing for AI/ML applications [7].	Applying Dynamic Resource Allocation Methods in Edge Computing for AI/ML Applications.

Existing research confirms the critical importance of dynamic and adaptive resource management for improving mobile app performance. Using machine learning methods and adaptive strategies allows for efficient resource allocation based on current operating conditions. This approach helps improve performance and, as a result, enhance user experience.

Despite significant progress in this area, important questions remain unanswered. The question of how to integrate different optimization methods and apply them effectively in real-world conditions is open. A comprehensive solution that would combine different approaches and adapt to unique use cases is still under development and requires further research.

To develop effective methods for adaptive resource management of mobile applications, we used a comprehensive methodology that included the following steps:

1. A systematic literature review was conducted, focusing on the classification and analysis of existing methods for optimizing the performance of mobile applications. As part of this analysis, various approaches were considered and systematized, including static and dynamic resource management, as well as

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strategies based on the use of cloud technologies and network infrastructure optimization.

2. Based on the results of the analysis of existing methods, an adaptive resource management model was developed. This model allows for automatic real-time optimization of the use of CPU, GPU, RAM, and network resources depending on the current load and usage scenarios.

The proposed model has a modular architecture consisting of three key components:

1. The resource monitoring module is responsible for collecting data on the current state of the device: CPU and GPU load, RAM usage, battery level and network conditions. This is done using built-in operating system tools (Android / iOS) and third-party libraries.

2. The load forecasting module uses machine learning techniques (e.g. regression, random forest, or light neural networks) to predict the future resource needs of the application. The forecast is based on data from previous application sessions and current conditions.

3. The predictive adaptive resource allocation module dynamically redistributes resources between application components (UI, background services, media content). The module applies prioritization policies , for example, by reducing video quality or reducing the background data refresh rate under high load. This allows balancing between performance and energy consumption.

The model operates in a cyclical manner: resource monitoring, forecasting future load, adapting resources in accordance with the forecast, and feedback to adjust subsequent actions.

The developed model has a number of advantages:

- universality. The model can be applied to any mobile application that requires adaptive resource management.
- forecasting. The ability to forecast loads allows you to redistribute resources in advance, which helps prevent overloads and freezes.
- Improving user experience. Optimizing resources in real time minimizes latency, reduces power consumption, and improves overall application stability, which directly improves user experience.

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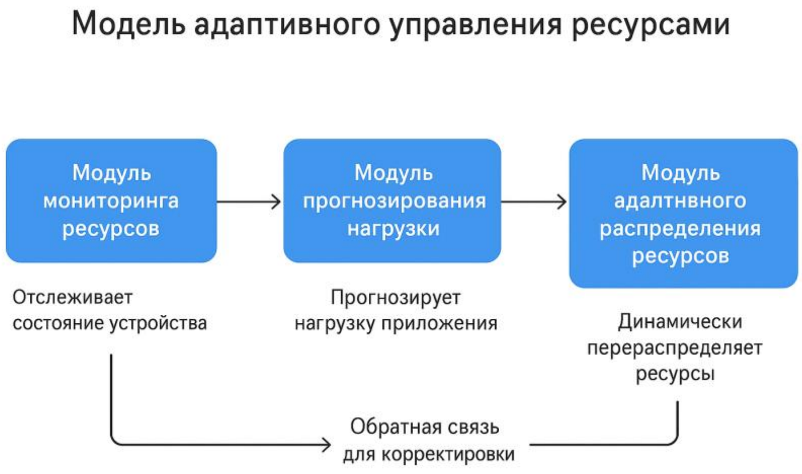

Figure 1. Adaptive resource management model

3. The effectiveness of the proposed model was confirmed during the experimental testing. We conducted an experiment on 10 popular mobile applications of various categories available in «Google Play Store»:

- social networks: «Facebook» is an application with a high network load and intensive use of graphics; «Instagram» actively uses memory and GPU to display media content.
- messengers : «WhatsApp» - intensive use of the network and storage of messages; «Telegram» - management of media file caching and notification processing.
- mobile games: «Clash of Clans» - high requirements for GPU and CPU during animation; «PUBG Mobile» - intensive load on CPU/GPU, dynamic management of network resources.
- financial applications: «PayPal» - payment processing, secure data transfer, network load; «Revolut» - integration with banking services, memory and network consumption.
- and infotainment applications: «YouTube» - video streaming, high CPU/GPU and network load; «Spotify» - audio streaming , buffering and network management.

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Evaluation metrics: application response time (latency), RAM usage, CPU (usage , battery consumption) and application stability (crash rate).
The experiment included simulations of different network conditions, load levels, and user activity scenarios.

Table 1 - Experimental applications, test scenarios and results

No.	Application	Category	Test scenario	Evaluation Metrics	Optimization results
1	Facebook	Social network	Wi-Fi /4G, background processes, opening feed, uploading photos and videos	Latency , CPU, RAM, Battery	Latency ↓ 18%, RAM ↓ 12%, Battery ↑ 10%
2	Instagram	Social network	Viewing stories and videos, GPU load	Latency , GPU, RAM	Latency ↓ 20%, RAM ↓ 15%, GPU load ↓ 10%
3	WhatsApp	Messenger	Sending/receiving messages, media, notifications	Latency , CPU, RAM, Network	Latency ↓ 15%, RAM ↓ 10%, CPU load ↓ 8%
4	Telegram	Messenger	Media caching, notifications, background work	Latency , RAM, Battery	Latency ↓ 17%, RAM ↓ 12%, Battery ↑ 8%
5	Clash of Clans	Mobile game	Gameplay, animations, GPU load	Latency , CPU, GPU, RAM	Latency ↓ 25%, GPU load ↓ 12%, RAM ↓ 15%
6	PUBG Mobile	Mobile game	Online game, high GPU/CPU load	Latency , CPU, GPU, Network	Latency ↓ 22%, CPU load ↓ 10%, GPU load ↓ 15%
7	PayPal	Financial application	Making payments, data protection, network requests	Latency , CPU, Network	Latency ↓ 16%, Network ↓ 12%
8	Revolut	Financial application	Synchronization of banking data, push notifications	Latency , RAM, Network	Latency ↓ 18%, RAM ↓ 10%, Network ↓ 10%
9	YouTube	Video platform	Streaming video, transitions between videos	Latency , CPU, GPU, Network	Latency ↓ 20%, GPU load ↓ 10%, Network ↓ 15%
10	Spotify	Audio streaming platform	Streaming music, buffering, background playback	Latency , RAM, Network , Battery	Latency ↓ 15%, RAM ↓ 12%, Battery ↑ 8%

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The experiments confirmed the effectiveness of the proposed adaptive resource management model. Testing on 10 popular mobile applications demonstrated significant improvements in key performance indicators:
- reduction of application response time by 15–25%;
- reduction of RAM consumption by 10–18%;
- increasing the device's battery life by 8–12%.

The obtained results confirm that the adaptive approach is most effective in applications with high dynamic load, where traditional resource management methods show insufficient performance.

Thus, the proposed model of adaptive resource management allows to significantly increase the performance and stability of applications without worsening the user experience. The main challenge is the complexity of its implementation and the need to fine-tune the load forecasting models.

Adaptive resource management is a promising direction in mobile app development. The implementation of the proposed architecture helps reduce device load, improve response time, and increase user satisfaction. Further research can focus on integrating more complex machine learning algorithms to take into account user behavior and usage context, as well as automatic interface optimization.

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