CSE 506 Operating Systems
Paper 3

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Paper Number: 3
Paper Title: LegoOS: A Disseminated, Distributed OS for Hardware Resource Disaggregation
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1. What problem does the paper address? How does it relate to and improve upon previous work in its domain? (one paragraph, <= 7 sentences)

The paper tackles the challenge of hardware resource disaggregation within operating systems, introducing LegoOS (like the concept of Lego Bricks) as an innovative solution to address existing inefficiencies. In contrast to traditional monolithic architectures, LegoOS aims to overcome limitations such as **inefficient resource utilization, inflexible hardware configurations**, **coarse failure domains** and **bad support for heterogeneity**. The monolithic approach leads to inefficient resource utilization, as tasks are confined to specific machines, causing eviction even in low overall utilization scenarios. Secondly, the rigid nature of monolithic servers makes it challenging to adapt to changing hardware requirements quickly. Thirdly, when any hardware component fails, the entire server goes down. LegoOS proposes a hardware disaggregation model, dispersing resources into network-attached components, each with its controller and network interface. This model enhances flexibility, elasticity, and failure isolation, allowing for a more dynamic and heterogeneous approach to hardware deployment, accommodating various devices such as GPGPUs, TPUs, NVM, etc.

2. What are the key contributions of the paper? (one paragraph <= 7 sentences)

LegoOS involves its splitkernel architecture, which breaks down traditional OS functions into **loosely-coupled monitors** managing different hardware components, including **pComponent (processor), mComponent (memory), and sComponent (storage)** communicating through network messaging. It includes the **clean separation of process and memory functionalities**, with memory management moved to mComponents, while utilizing a combination of hardware and software for cache management. It operates as a distributed OS, presenting itself to applications as a **set of virtual servers (vNodes)** running on distributed hardware components. The design principles emphasize efficient resource distribution, utilizing a global strategy for selecting pComponents, and introducing the concept of **ExCache as a virtual cache** for private memory. The design also incorporates global resource managers for coarse-grained resource allocation and load balancing, enhancing flexibility and scalability. Furthermore, LegoOS is backward compatible with Linux ABIs, allowing seamless integration with existing applications. Further, evaluation results demonstrate promising performance improvements compared to traditional monolithic server architectures.

3. Briefly describe how the paper's experimental methodology supports the paper's conclusions. (one paragraph <= 7 sentences)

The paper presents a comprehensive experimental methodology to substantiate its conclusions regarding the effectiveness of LegoOS in addressing hardware resource disaggregation challenges. The experiments were conducted on a cluster of 10 machines with Intel Xeon processors. Firstly, the **micro- and macro-benchmark evaluations**, comparing the performance of LegoOS's memory and storage components with a single-node Linux system. These benchmarks demonstrate that LegoOS outperforms Linux in terms of network latency, memory throughput, and storage operations. It also evaluates using workloads from the PARSEC benchmark suite, demonstrating its performance across compute-intensive datacenter applications. **Real-world applications**, including TensorFlow and Phoenix MapReduce, are used to evaluate LegoOS's performance in practical scenarios, showcasing its efficiency in handling diverse workloads. The experiments also include a comparative analysis of failure rates, showing that LegoOS improves **Mean Time to Failure (MTTF)** by 17% to 49% compared to an equivalent monolithic server cluster, highlighting its enhanced resilience across different aspects of resource disaggregation and system performance.