TTHE ADJUDICATION COMMITTEE'S EVALUATION OF THE CANDIDATE'S DISSERTATION
(Is to be submitted to the Department 5 weeks prior to the planned disputation,
the evaluation must reach the Faculty no later than 4 week before the planned defence)

The adjudication committee has had the following members:

Professor Zsolt István, Technische Universität Darmstadt, *Germany*

Professor Mei Wen, National University of Defense Technology (NUDT), China

Professor Tor Skeie, Department of informatics, University of Oslo

Jonas Sæther Markussen has written the dissertation with the title:

SmartIO: Device sharing and memory disaggregation in PCIe clusters using non-transparent bridging

Evaluation of the candidate's dissertation, each of the following aspects must be answered:

The dissertations field of research:

The work presented in the dissertation can be described as a combination of Operating Systems research，Cluster computer system, Memory Disaggregation, and interconnection networks research. The main results of the work are in providing an implementation and evaluation of a novel way of connecting together multiple computers in a cluster and enabling their operating systems to access devices situated in remote computers as if they would be local.

The content and objective of the dissertation (short description, work of great merit and other important details on the theoretical and/or experimental side should be mentioned):

The main research question this dissertation explores is: Can non-transparent PCIe bridges (NTBs) be leveraged to allow the internal memory and devices of individual computers in a cluster to be shared with and used by remote machines in the same cluster?

The work defines several high-level objectives related to answering this question. First, it aims to provide «ubiquitous sharing», in that any machine is able to share any of its PCIe devices and access remote devices as if they would be local (both in terms of access interface and performance profile). Second, device sharing across distributed machines should be done in a dynamic fashion, allowing run-time addition and removal of shared devices, as well as, sharing the same physical resource with multiple other computers at the same time, even if said resource has not been designed with such sharing in mind.

The dissertation presents a complete solution to the research question and demonstrates, with a rich set of experiments, that the performance overhead of device sharing using PCIe NTB is minimal. Not only is the amount of technical contribution impressive, the explanations presented both in the dissertation and the individual research papers (five in total) are clear in explaining how various design decisions led to the minimization of overheads.

All five research papers submitted with the dissertation were published in international conferences or journals targeting different sub-areas of the systems community. The most noteworthy of these is a comprehensive journal publication entitled "SmartIO: Zero-overhead Device Sharing through PCIe Networking" that appeared in the ACM Transactions of Computer Systems, a prestigious Q1 journal with the widest reach of the five venues and very high visibility across all areas of the systems community.

The candidate's original contribution and independence in research:

The main contribution of the candidate is developing a framework called SmartIO for sharing resources and distributing devices in a heterogeneous, PCIe-networked cluster with integrated NTBs, which is all about proposing and executing cross-layer solutions. That is, solving research problems that span application, OS, driver, and hardware layers. The ability to work across all layers, to understand how to balance conflicting requirements, and to implement practical solutions is rare – it clearly shows that the doctoral candidate has the capacity to carry out impactful and independent research. It has to be mentioned that, in addition to the technical contributions, the candidate shows great ability in summarizing and contrasting to state of the art. This results in design decisions that are well argued for and hence convincing to the reader.

The scientific standard of the dissertation (strength and weaknesses):

S1. The design decisions in this work are well researched and backed up by arguments from state of the art.
S2. The explanations are outstanding. All illustrations, description of experiments and experimental results are very clear and easy to follow.
S3. The work acts as a platform for further research (and development). By using the SmartIO full-stack implementation, it is possible to build distributed applications that otherwise would either not be possible or would incur large performance overhead.

W1. Generally, more end-to-end examples of applications benefitting from the proposed platform could have been included. It is true that the existing experiments already cover most performance aspects, but a detailed study of real-world applications might provide more insight on which metrics are worth optimizing in the future (instead of focusing on all metrics at the same time).
W2. Looking into the future, the dissertation could have articulated better the opportunities for hardware/OS designers, when designing the next generation of PCIe-attached accelerators. Expert readers can already imply some ideas about future bottlenecks/issues in the text, but these could have been made more explicitly by the candidate.

The candidate's perspective on the research area and his/her ability to view own research in a greater context:

The dissertation is a proof that the candidate has an objective view of his work in terms of contributions. The contributions listed in the dissertation are solid and they are neither over-claimed nor under-claimed. In addition to this, there are reflections in the text regarding the research methodology adopted and this shows that the candidate has put significant thought not only into what topics to investigate, but also into how to conduct this research activity. The candidate has an impressive understanding of performing system integration with respect to multiple software levels including OS, runtime, drivers etc.

The technical quality of the dissertation (outline, depiction, general impression, level within an international setting):

Overall, the dissertation is of very high quality, and is considered above average in an international setting.

The presentation and quality of explanations is outstanding. The dissertation is concise and complete at the same time. The introductory chapters provide all relevant high-level information and further sections and attached papers provide the "deep-dives". Experiments cover all claims made by the candidate. Furthermore, clear illustrations make it easy for the readers to understand the concept.

One aspect that has to be highlighted is the impressive quantum of technical contributions and implementation effort for building a complete platform for device sharing.

Other comments (any dissents in the committee should be mentioned here):

The report shall conclude whether the dissertation is worthy of being defended:

☒ The dissertation is worthy of defense without changes

☐ The dissertation is worthy of defense, but the dissertation or the scientific work has minor shortcomings that should be corrected before the defense. The candidate should normally be able to do this within two months. No re-examination is necessary.

☐ The dissertation is possibly worthy of defense, but the dissertation or the scientific work has major shortcomings that should be corrected before it can be defended. The candidate should normally be able to do this

within six months. The dissertation should be re-examined by the original adjudication committee before final approval for defense.
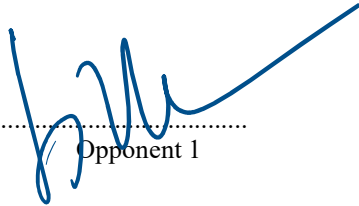
☐ The dissertation or the scientific work falls short of the standards required for a PhD, and it is found not worthy of defense.

PLACE: Oslo   DATE: Sept. 5 - 2022

SIGNATURES:

Zsolt István   **Mei Wen**   **Tor Skeie**

....
Opponent 1   Opponent 2   Administrator

.