Introduction
Imperix’s main product, the BoomBox, is a modular control platform used to develop power converters.

This project consists of the study and implementation of a solution to connect multiple BoomBoxes using serial communication. The challenge comes in the need of very low communication delays (tens of µs) in order to close the control loop quickly, even with hundreds of I/Os.

Method
To select the best network topology for a control network, we modelled the sensor and actuator transfer delays in function of the device-to-device latency and the packet transmission delay.

We selected a set of eligible communication protocol candidates for FPGA-to-FPGA communication (Ethernet, PCIe, Serial RapidIO and Aurora) and studied their advantages and downsides for our application. We designed and implemented a custom communication protocol that defines application-layer services. They use efficient DMA mechanisms and scheduled sensor data collection to achieve the lowest transfer delays possible.

We validated the proposed solution on a real system constituted of 8 FPGA-based devices interconnected in daisy-chain.

Results
We established that the tree network with a fanout of 2 is the best topology for our application and showed that a higher fanout would not bring any substantial benefit due to channel saturation. We showed that popular general-purpose protocols are not suited for networked control systems and adopted instead the Aurora 8b/10b protocol. Our custom solution shows a protocol efficiency up to 90% with payloads as small as 60 octets and can exchange data of 256 I/Os in less than 4 µs. The results validate a-posteriori the defined daisy-chain performance model.

Conclusion/Perspectives
The implemented solution functions as expected and shows satisfying performance. With the implemented solution we expect transfer delays 10x smaller than the current system. In the future, the solution could be upgraded to support tree topologies for even better performance.

Acknowledgments
Thanks to imperix for giving me the opportunity to realize this project and to René Beuchat for its supervision.